

### **REMARKS**

This responds to the Office Action mailed on February 2, 2009.

Claims 1, 4-5, 7 and 9-13 are amended and claim 6 is canceled. Claims 1-5 and 7-14 are pending in this application.

The Examiner objected to claims 1-7 and 9-10 stating that the claims contain the acronym "iscom" and requesting the acronym be capitalized in the first recitation and include the full recitation followed by the acronym in parenthesis. Applicant has amended the claims as required by the Examiner. Applicant respectfully submits that the amendment renders the objection moot and respectfully requests withdrawal of the objection of claims 1-7 and 9-10.

#### **The 35 U.S.C. § 112, First Paragraph, Rejection**

Claims 11-13 were rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. Applicant respectfully submits that the amendment to claims 11-13 renders the rejection moot. Thus, Applicant respectfully requests withdrawal of the rejection of claims 11-13 under § 112(1).

#### **The 35 U.S.C. § 112, Second Paragraph, Rejections**

Claims 1, 4-7 and 11-13 were rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Applicant respectfully traverses this rejection.

With regards to claims 1 and 4-6, Applicant respectfully submits that the amendments to claims 1 and 4-6 renders the rejection moot. Therefore, Applicant respectfully requests withdrawal of the rejection of claims 1 and 4-6.

With regards to claims 1, 5, 7 and 11-13, the Examiner alleges that the skilled artisan would not be readily apprised of the metes and bounds of the phrase "fragment A of Quil A" as this term is not a recognized term nor defined in the specification. Applicant respectfully submits that the claims recite "fraction A of Quil A" and not "fragment." Additionally,

Applicant respectfully submits that the phrase “fraction A of Quil A” is an art recognized term and is defined in the specification. For example, in lines 1-5 of WO 2005/002620 (corresponding to the instant application) it is mentioned that fraction A is described in WO 96/111711, which is the cited Cox patent application, and in EP 0 436 620. Additionally, at page 8, lines 12-22, of the instant application as originally filed it is disclosed that fraction A is prepared from the lipophilic fraction obtained on chromatographic separation of crude aqueous extract and elution with 70% acetonitrile in water to recover the lipophilic fraction. The lipophilic fraction is then separated by semipreparative HPLC with elution using a gradient of from 25% to 60% acetonitrile in acidic water. The fraction referred to herein as “Fraction A” or “QH-A” is the fraction which is eluted at approximately 39% acetonitrile. Thus, Applicant respectfully submits that the metes and bounds of the phrase “fragment A of Quil A” is definite. Therefore, Applicant respectfully requests withdrawal of the rejection of claims 1, 5, 7 and 11-13.

Regarding claims 11-13, the Examiner stated that there was insufficient antecedent basis for the phrase “fragment A of Quil A” in the claim. Applicant respectfully submits that the amendments to 11-13 renders this rejection moot. Applicant respectfully requests withdrawal of the rejection of claims 11-13.

Applicant respectfully submits that the claims comply with 35 U.S.C. § 112, first and second paragraph. Thus, Applicant respectfully requests withdrawal of these rejections.

#### The 35 U.S.C. § 102(b) Rejection

Claims 1-2, 4-9 and 14 were rejected under 35 U.S.C. § 102(b) as being anticipated by Friede et al. (U.S. Patent No. 6,558,670 Publication Date May 6, 2003). Applicant respectfully traverses this rejection.

1) Saponin fraction A of Quil A, which must be present in Applicant’s invention, differs from the closest fraction (QS 7) mentioned, but not tested or preferred, in Freide et al.

Page 4 of the instant Office states that "Friede et al does not differ in any way." Applicant respectfully submits that this statement is incorrect. Applicant respectfully submits that there is a difference in the saponin fraction A of Quil A, which must be present in Applicant's invention, and the closest fraction QS 7 mentioned, but not tested or preferred, in Freide et al.

The present invention relates to the use of fraction A of Quil A. In the event that the present invention is used together with the oligonucleotide CpG as the at least one other adjuvant, it may be looked upon as a selection invention of Friede et al., i.e. a selection from saponins generally mentioned in Friede et al. However, in the Friede et al. patent, haemolytic saponins are preferred (see below) and the essential saponin of the present invention, fraction A of Quil A, is not haemolytic, *nor mentioned* in Friede et al. One saponin mentioned in Friede et al. is fraction QS 7 of Quil A. Fraction QS 7 is enclosed in fraction A of Quil A. However, fraction A also contains saponins other than QS 7.

Fraction A is composed of several Quil A saponins among them QS 4, 5, 6 and 7, see US Pat No. 5,057,540 (Kensil et al.; enclosed herewith for the Examiner's convenience). Fraction A is shown in Enclosure 1 (enclosed herewith), which is a HPLC diagram of fraction A and C prepared by the Applicants. Fraction A, is prepared from the lipophilic fraction obtained on chromatographic separation of the crude aqueous Quil A extract and elution with 70% acetonitrile in water to recover the lipophilic fraction. The lipophilic fraction is then separated by semipreparative HPLC with elution using a gradient of from 25% to 60% acetonitrile in acidic water. The fraction referred to herein as "Fraction A" or "QH-A" is the fraction which is eluted at approximately 39% acetonitrile (please see the cited Cox application WO 96/111711, page 7 lines 21-30).

The QS 7 fraction was prepared from aqueous extracts of the Quillaja saponaria Molina bark which were dialyzed against water. The dialyzed extract was lyophilized to dryness, extracted with methanol and the methanol-soluble extract was further fractionated on silica gel chromatography and by reverse phase high pressure liquid chromatography (RP-HPLC) USP 5, 0570, 540 column 4 lines 55-63. FIG. 3 shows the comparison of Superfos "Quil-A" and dialyzed methanol soluble bark extract by HPLC.

FIG. 5B demonstrates the purity of QA-7, QA-17, QA-18, and QA-21 by normal phase (5B) thin layer chromatography.

Fraction A of Quil A is obtained by a different method than the fraction QS7 and is more crude in that it among other fractions also comprises fraction QS 7.

2) Saponin fraction A of Quil A of the present invention has a different effect than fraction QS 7 mentioned, but not tested or preferred, in Friede et al.

As mentioned, Friede et al. specifically state that haemolytic saponins are preferred. This is disclosed in column 2, lines 61-63, "particularly wherein said saponins have haemolytic activity. Preferred saponins include Quil A, QS 1, QS 21, QS 7...." Further, it is stated in column 4, line 66 to column 5, line 4, "[f]or the purposes of this invention the saponin adjuvant preparation is haemolytic if it lyses the erythrocytes at a concentration of less than 0.1%. As means of reference, substantially pure samples of Quil A, QS21, QS7, Digitonin, and  $\beta$ -escin are all haemolytic saponins as defined in this assay." In column 5, lines 13-15, it is once again stated that "[t]he final formulations in the form as they are administered to the mucosal surface of the vaccine are preferably haemolytic in nature." Finally, at the end of the example in column 12, lines 10-12, "taken together, these results show clearly the potential of intranasal formulations combining a lytic saponin and an immunostimulant."

Thus, it is submitted that as Friede et al. prefer haemolytic formulations, ISCOMs are not at all suitable. A present inventor, Morein, and other experts have described in numerous articles that the haemolytic activity of the saponins is abolished by the incorporation into ISCOM structures. This is evident from Drane et al., *Expert Rev Vaccines* 6(5), 772, 2007 (page 762 left column lines 22-25; a copy of which is enclosed herewith for the Examiner's convenience).

Furthermore, fraction A of Quil A used according to the present invention is not haemolytic. This is evident from the cited Cox document (WO 96/11711). Table 1 on page 8 of WO 96/11711 shows that fraction A has very low haemolytic activity. Additionally, fraction A of Quil A is integrated into an ISCOM according to the present invention, which makes even haemolytic saponins non-haemolytic.

3) Saponin fraction A of Quil A that must be present in Applicant's invention differs from the saponin QS 21 disclosed, preferred and tested by Friede et al.

Applicant respectfully submits that there is a difference in the saponin fraction A of Quil A that must be present in Applicant's invention and the saponin QS 21 disclosed, preferred and tested by Friede et al.

Fraction C of Quil A comprises fraction QS 21 tested in the example of the Friede et al. patent. However, fraction C also contains saponins other than QS 21. Fraction A, which must be comprised in the composition according to the present invention, is quite another fraction of Quil A than fraction C or QS 21.

It has been presented above how fraction A is produced according to the instant disclosure and the cited Cox document (WO 96/11711). Enclosure 1 shows that fraction C comprises fraction QS 21 and also other fractions of Quil A. In the cited Cox document (WO 96/11711) at page 7, line 21 to page 8, line 2, it is described that fraction C is produced like fraction A, but is eluted at approximately 49% acetonitrile. Therefore, it is evident that fraction C is different from fraction A.

Further, US Pat. No.5,057,540 describes at column 4 and 5 and in Example 1 that fraction QS 21 is prepared as fraction QS 7 but is obtained as a later fraction with higher retention time. It is evident that fraction QS 21 which is a saponin fraction comprised in fraction C is different from fraction A.

4) Saponin fraction A of Quil A, which must be present in Applicant's invention, has another effect than saponin QS 21 disclosed, preferred and tested by Friede et al.

Fraction A of Quil A used according to the present invention is not haemolytic. This is evident from the cited Cox document (WO 96/11711). Table 1 on page 8 of WO 96/11711 shows that fraction C, which is close to QS 21, has high haemolytic activity. This is also the saponin that Friede et al. prefer and use.

In column 2, lines 19-22, Friede et al. refer to the haemolytic saponins QS21 and QS17 of US Pat. No. 5,057,540. Figure 10 of US Pat. No. 5,057,540 shows that QS21 and 17 are indeed haemolytic at around 10 µg/ml.

Another difference between fraction A of Quil A and fraction QS 21 preferred and tested in Friede et al. is the type of immunological reaction induced. In the response dated October 27, 2008, Applicant provided an attachment titled "Intranasal administration of PR8 micelles," which provided results from an assay in which the Applicant tested fraction A and C from Quil A in an intranasal administration of fraction A and C of Quil A in free form. It is evident from the results that Fraction A of Quil A does not improve the IgA titre (columns 2, 3 and 4 of the figure) after intranasal administration. This example confirms the intranasal adjuvant effect of Fraction-C, which comprises fraction QS 21 and other saponins. However, no such effect is shown with Fraction-A. In a supplemental response to be filed shortly, Applicant will provide this information in a declaration executed by one of the inventors so as to have the Examiner fully consider this evidence.

Therefore, Applicant respectfully submits that claims are novel in view of Friede et al. Thus, Applicant respectfully requests withdrawal of the rejection under § 102(b).

#### The 35 U.S.C. § 103(a) Rejection

Claims 1-14 were rejected under 35 U.S.C. § 103(a) as being obvious over Friede et al. (U.S. Patent No. 6,558,670) in view of Cox et al. (WO 96/11711). Applicant respectfully traverses this rejection.

Friede et al. disclose that that immune-stimulatory oligonucleotides (CpG) and saponin combinations are potent adjuvants (col. 3 l. 25-27). Friede et al. specifically state that haemolytic saponins are preferred (see, for example, column 2, lines 61-63, column 4, lines 66 to column 5, line 4, and column 5, lines 13-15). Fraction A of Quil A is not mentioned at all in Friede et al.

Fraction A of Quil A is not haemolytic. This is evident from the cited Cox patent application WO 96/11711. Table 1 on page 8 of WO 96/11711 shows that fraction A has very low haemolytic activity. Consequently Friede et al. teaches away from using fraction A of Quil A, as fraction A is not haemolytic.

Applicant respectfully submits that a skilled person reading Friede et al. which discloses that haemolytic saponins are preferred would not consider using fraction A upon reading Cox. Therefore, the skilled person would not combine Friede et al. with Cox.

Even if, for the sake of argument, the skilled person would revert to Cox if considering using fraction A of Quil A as an adjuvant together with another adjuvant, the skilled person would *not* consider using fraction A and fraction C in different ISCOM particles or with fraction A integrated into an ISCOM particle and fraction C in free form. The Cox patent only relates to the integration of fractions in the same ISCOM complex.

Friede mentions that the saponin may be in the form of ISCOM col. 5 lines 8-10. However, experts have described in numerous articles that the haemolytic activity of the saponins is abolished by the incorporation into ISCOM structures. Thus, even in mentioning ISCOM, Friede et al. teach away from using ISCOMs, as Friede et al. clearly state that haemolytic saponins are preferred.

Thus, the claims are not obvious over Friede et al. (U.S. Patent No. 6,558,670) in view of Cox et al. (WO 96/11711). Therefore, Applicant respectfully requests the withdrawal of the rejection under 103(a).

### CONCLUSION

Applicant respectfully submits that the claims are in condition for allowance, and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's representative at (612) 373-6905 to facilitate prosecution of this application.

If necessary, please charge any additional fees or deficiencies, or credit any overpayments to Deposit Account No. 19-0743.

Respectfully submitted,

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Date August 3, 2009

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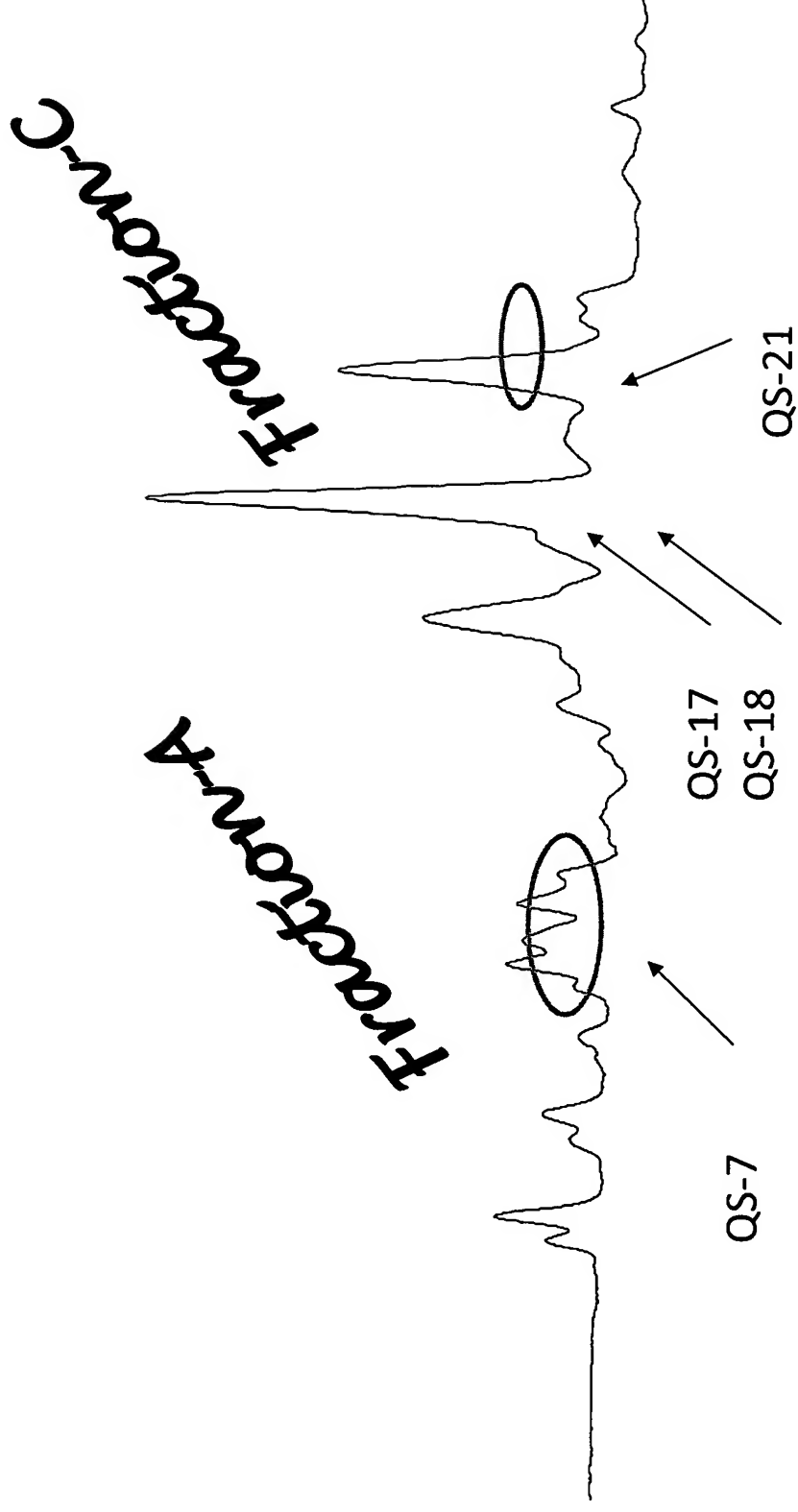
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# Enclosure 1





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## KEYWORDS

adjuvant; antibody  
immunotherapy; ISCOMATRIX;  
T-cell vaccine

# ISCOMATRIX™ adjuvant for prophylactic and therapeutic vaccines

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The ISCOMATRIX™ adjuvant has antigen-delivery and -presentation properties, as well as immunomodulatory capabilities that combine to provide enhanced and accelerated immune responses. The responses are broad, including a range of subclasses of antibodies as well as both CD4<sup>+</sup> and CD8<sup>+</sup> T cells. A range of ISCOMATRIX vaccines (ISCOMATRIX adjuvant combined with antigen) have been evaluated in clinical trials. The results of these completed and ongoing studies indicate that the ISCOMATRIX adjuvant is safe and generally well tolerated and increases the vaccine immune responses.

*Expert Rev. Vaccines* 6(5), 761–772 (2007)

The ISCOMATRIX™ adjuvant derives from the 'immunostimulating complex' or 'ISCOM', which was first described by Morein and colleagues in 1984 (1). They subsequently showed that ISCOM-like structures could form in the absence of immunogen and called these structures ISCOM matrix (2). The classical ISCOM™ vaccine required the incorporation of an amphipathic protein, typically a membrane protein, into a nascent structure that also required saponin, cholesterol and phospholipid for its formation. This not only restricted the types of proteins able to be formulated into a vaccine but also required a process that was complex and difficult to control. Our proprietary ISCOMATRIX adjuvant, which contains only a purified fraction of *Quillaia* saponin, cholesterol and phospholipid, can be made by a simple and robust manufacturing process. This can then be formulated with virtually any antigen to produce an ISCOMATRIX vaccine. A range of ISCOMATRIX vaccines have been tested in clinical trials and have been generally safe and well tolerated as well as immunogenic, generating both antibody and T-cell responses (for review see (3)). This makes the ISCOMATRIX adjuvant suitable for use in both prophylactic and therapeutic vaccines, which generally require antibody and cellular responses, respectively. In recent years, the focus has

been on developing an improved ISCOMATRIX adjuvant to meet more easily the ever increasing regulatory standards for components of human vaccines, while maintaining the strong immune responses. The result is an optimized ISCOMATRIX adjuvant that is well defined, has minimal impurities and does not use any materials of animal origin. Additionally, improvements have been made to the methods of manufacture to ensure product can be manufactured reliably at any relevant scale. There has also been a much greater understanding of the mechanism of action of the ISCOMATRIX adjuvant.

## Preparation & properties of ISCOMATRIX adjuvant

### Composition

The ISCOMATRIX adjuvant contains saponin, cholesterol and phospholipid, typically in a phosphate-buffered saline (PBS) at pH 6.2. These components will be considered in turn.

Saponin, which comes from the bark of the *Quillaia saponaria* tree, is the potent immunomodulatory component. *Q. saponaria* saponins have been used for many years as adjuvants in animal vaccines, although these crude preparations are not suitable for human use owing to their toxicity and complexity (4). More defined fractions of *Quillaia* saponin

have been developed including QS21 [5], ISCOMPREP™ 703 [6] and, more recently, ISCOMPREP saponin. Apart from the obvious reduction in complexity, each of these fractions is selected to maximize adjuvant activity and minimize toxicity. CSL's prototype ISCOMATRIX adjuvant, from the mid 1990s, used ISCOMPREP 703, which contained seven parts of fraction A and three parts of fraction C from *Quillaia* saponin. More recently, CSL has further developed a proprietary process for the fractionation of *Quillaia* saponin for use in its optimized ISCOMATRIX adjuvant. The resulting ISCOMPREP saponin does not contain fraction A and thus avoids the complexity of ISCOMPREP 703 and permits the characterization that is essential for materials to be used in human vaccines. The improved fractionation process also includes additional chromatography steps to eliminate impurities from the bark.

Cholesterol, which is synthesized from a plant precursor, interacts irreversibly with saponin. This interaction protects the saponin from hydrolysis and hence adds substantially to the stability of the ISCOMATRIX adjuvant [7]. Another critical feature of this interaction is that the ability of the saponin to interact with membranes is eliminated effectively. As a result, the hemolytic activity of saponin, which has been linked with the severe dose site reactions and other adverse events seen with QS21 [8], is essentially lost.

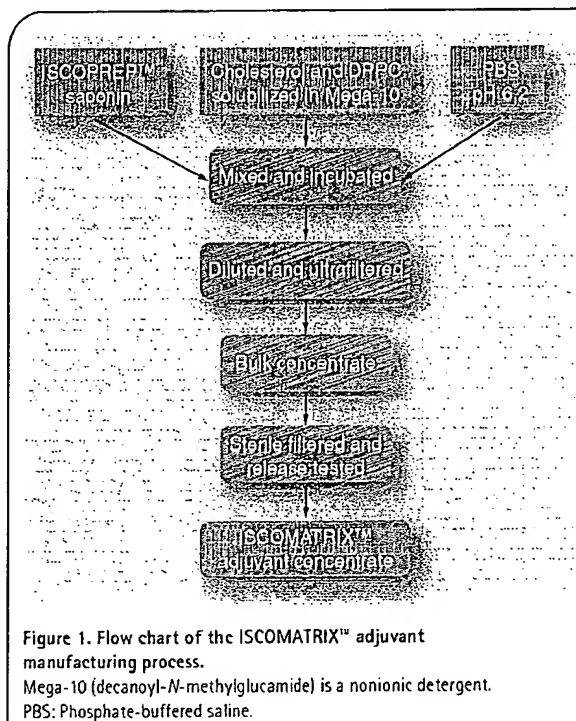
The phospholipid component contributes to the morphology and stability of the ISCOMATRIX adjuvant [9]. Phosphatidylcholine (PC) was traditionally used in ISCOM vaccines as it was identified as a component of the cell membrane required for consistent formation of ISCOM vaccines. However, commercially available PC is generally egg derived and is a complex mixture of molecules with different acyl chains. Dipalmitoyl-phosphatidylcholine was identified as the optimal phospholipid for the manufacture of ISCOMATRIX adjuvant for use in human vaccines as both acyl chains are the same and it is manufactured synthetically from plant-derived starting materials.

All of the components of the ISCOMATRIX adjuvant can be defined chemically and are either synthetic or derived from plant materials. In addition, there are no components or reagents used in the manufacturing process that are of animal origin. All raw materials are sourced from reputable suppliers and meet the stringent requirements for use in human vaccines.

#### Manufacturing processes

The manufacturing processes for both ISCOMPREP saponin and ISCOMATRIX adjuvant are performed in accordance with good manufacturing practices in high-quality purpose-built facilities in the USA and Australia. The processes have been optimized extensively to ensure a consistent and effective product and extensive in-process and final testing is performed to guarantee compliance.

The ISCOMATRIX adjuvant manufacturing process is relatively simple as shown in FIGURE 1, and can be scaled easily to commercial production capacity as required. The cage-like



structures of the ISCOMATRIX adjuvant form spontaneously when the components are mixed as described and exist in a low-energy state making them very stable. ISCOMATRIX adjuvant is provided as a sterile bulk concentrate at approximately 4 mg saponin/ml in PBS pH 6.2 and can be stored at 2–8°C where it is stable for at least 2 years. The release specification includes tests for identity, content, safety and biological activity but does not include a potency test as this would be performed on the vaccine formulation. Characterization, however, includes a range of immunological readouts in animal models, as well as further physicochemical analysis.

#### Physical properties

The particulate nature of the ISCOMATRIX adjuvant contributes to its antigen delivery capability. The cage-like structure and particle size, typically 40–50 nm in diameter, could be described as 'virus-like' enabling efficient phagocytosis by antigen-presenting cells (APCs). This feature is described in further detail later in this review under 'Mechanism of Action'.

The cage-like structure of the ISCOMATRIX adjuvant is best seen when examined by transmission electron microscopy (TEM). Techniques, such as cryoelectron microscopy and atomic force microscopy, have confirmed the spherical nature of the ISCOMATRIX adjuvant, as well as the particle size and ring-like subunit morphology as shown in FIGURE 2.

The molecular structure has not been fully elucidated, although the original model proposed by Kersten *et al.* in 1991 for the subunit structure has been generally supported by more recent studies using molecular dynamics (UNPUBLISHED DATA) [10]. It would appear that each of the ring subunits contains

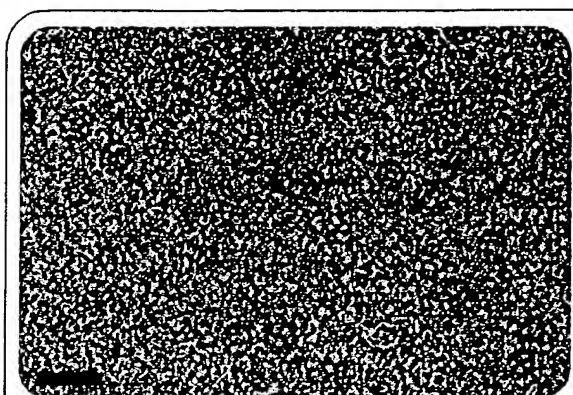


Figure 2. Thin-film cryoelectronmicrograph of ISCOMATRIX™ adjuvant. Bar = 100 nm. Image kindly provided by Ross Hamilton and Alex Hyatt.

saponin molecules inserted into a lipid bilayer in an extended conformation, such that both the triterpenoid core and acyl side chain interact with the bilayer in agreement with recent data using TEM by Myschik *et al.* [11].

The surface charge of the ISCOMATRIX adjuvant is approximately -20mV and is due to the glucuronic acid moiety in the saponin. This negative charge enables the ISCOMATRIX adjuvant to exist in solution as a stable colloid and can also contribute to formulation capabilities as described in the next section.

Both the particle size and high-performance liquid chromatography (HPLC) profile of its constituent saponin can be used to evaluate the stability of ISCOMATRIX adjuvant enabling a range of excipients and storage conditions including temperature to be easily evaluated. Studies show that ISCOMATRIX adjuvant remains stable in the presence of salts, sugars, denaturants, such as urea, and reducing agents (UNPUBLISHED DATA). Although stable in the presence of low concentrations of some detergents, ISCOMATRIX adjuvant can be broken down by higher concentrations of some detergents and studies would need to be performed for each detergent at the required concentration. A range of pHs have also been investigated and the ISCOMATRIX adjuvant is stable within the range pH 2–10. At low pH, it tends to aggregate, most probably due to a change in surface charge. At high pH, the ISCOMATRIX saponin undergoes alkaline hydrolysis that results in increased hemolytic activity and reduced immunological activity. This hydrolysis is enhanced at elevated temperatures, such as 50°C, although the ISCOMATRIX adjuvant has been shown to be stable at room temperature (25°C) for extended periods. Additionally, it can be stored frozen, repeatedly freeze-thawed, freeze dried and spray dried.

The physical properties of the ISCOMATRIX adjuvant, including its colloidal nature in solution and stability under a variety of conditions, permit formulation with a wide range of vaccine antigens. Generally, conditions can be found that meet the requirements of the antigen while maintaining the integrity of the ISCOMATRIX adjuvant structure.

#### Formulation methods

Formulation of ISCOMATRIX vaccines can be as simple as mixing the antigen and the ISCOMATRIX adjuvant and dispensing directly for use. In other circumstances, considerable effort may be required to optimize the conditions required to keep both the antigen and adjuvant in an optimally active form. The induction of antibody responses often requires the antigen to be maintained in a conformationally active form. Studies with ISCOMATRIX adjuvant have shown that simple mixing with antigens in a buffer compatible with the antigen results in an effective ISCOMATRIX vaccine. It should be noted, however, that the presence of detergents in the antigen buffer need to be evaluated because they may interfere with the integrity of the ISCOMATRIX adjuvant.

Induction of a cellular immune response appears to require the delivery of both the antigen and the ISCOMATRIX adjuvant to the same APC. To optimize this delivery, it is more efficient to have the antigen associated with the ISCOMATRIX adjuvant, which then requires, at least in animal models, less antigen to induce a strong cellular immune response. A number of methods have been developed to enable association of antigens with the ISCOMATRIX adjuvant. The simplest of these involves electrostatic binding of charged antigens [12]. The surface charge of standard ISCOMATRIX adjuvant is negative, which enables association with positively charged antigens. To accommodate negatively charged antigens, the surface charge of the ISCOMATRIX adjuvant can be altered by using different phospholipids or the charge of the antigen altered by adding positively charged sequences. The addition of charged sequences is particularly effective in peptide-based vaccines. Other novel methods that have been developed to enable association include the chelating ISCOMATRIX adjuvant, which contains a phospholipid with a chelating metal ion head group that can bind with a metal affinity tag, such as hexahistidine on an antigen [13].

#### Mechanism of action

ISCOMATRIX adjuvant possesses many integrated properties for the induction of immune responses. These include delivery and facilitation of antigen presentation, recruitment of immune cells to the draining lymph nodes via the induction of chemokines and cytokines and activation of the innate and adaptive immune systems (FIGURE 3). Understanding the relative importance of each of these features and how they integrate will be important for optimal use of the adjuvant in the clinic. Clearly, understanding the full details of this process at the molecular level is beyond the current state of scientific knowledge. However, as the range of immunological tools and reagents expands, so does the depth of our understanding of the immunological processes that underpin the potent properties of the ISCOMATRIX adjuvant. This is particularly relevant with regard to the capacity of the ISCOMATRIX adjuvant to induce CD8<sup>+</sup> T-cell responses. The adjuvant properties can be grouped into the broad categories of immunomodulation and antigen delivery [14] and are described in more detail later. Importantly, both the

immunomodulatory function, which can be attributed to the ISCOMATRIX adjuvant alone, and the delivery of antigen, which requires codelivery of the ISCOMATRIX adjuvant and antigen, are required for optimal CD8<sup>+</sup> T-cell induction. This dual role and requirement is why ISCOMATRIX adjuvant is referred to as an integrated adjuvant. As shown in FIGURE 4, delay in delivery of the ISCOMATRIX adjuvant or antigen by 3 h dramatically reduces the immune response compared with coadministration as ISCOMATRIX vaccine.

#### Immunomodulation

The ISCOMATRIX adjuvant alone (i.e., in the absence of antigen), has been shown to have potent immunomodulatory effects at the level of the draining lymph node in sheep [15] and in mice (MANUSCRIPT IN PREPARATION). A characteristic of this priming event is that following subcutaneous administration of ISCOMATRIX adjuvant, there is an increased expression of proinflammatory cytokines, such as IL-6, IL-8 and IFN- $\gamma$ . Concomitantly, the cellular output from the lymph node draining the injection site transiently (6–12 h) declines and then increases markedly above the resting levels 24–48 h later. Together, these observations demonstrate that ISCOMATRIX adjuvant is a potent immune modulator that both maximizes the number of low-frequency antigen specific cells entering the lymph node, thus increasing the potential for interaction with antigen or APCs, and orchestrates the local immune response via the induction of proinflammatory cytokines. Much of the early knowledge of the immunomodulatory capability of the ISCOMATRIX adjuvant has come from evaluations in animal models with ISCOM vaccines and, although this may be applicable, our more recent work has been focused strictly on the

ISCOMATRIX adjuvant. For example, it was reported that cytotoxic T lymphocyte (CTL) responses were reduced dramatically in *IL-12*-knockout mice administered an ovalbumin (OVA) ISCOM formulation [16]. Although in these studies, lipopolysaccharide (LPS) contamination was very low (reported at 2 ng/dose), we have not been able to demonstrate a definitive role for IL-12 in CTL induction when these residual levels of LPS were removed (FIGURE 5A). The simplest explanation is that the CTL response in the earlier study combined the additive effect of IL-12-dependent LPS stimulation and IL-12-independent ISCOMATRIX adjuvant stimulation. Thus, it is critical that the analysis of which cytokines or chemokines are involved in the immune actions of ISCOMATRIX vaccines *in vivo* be conducted in the complete absence of LPS in order for clear interpretations to be made. Activation of the innate immune response in mice by ISCOMATRIX adjuvant does not appear to be mediated directly by Toll-like receptors (TLRs). We have shown that CTL responses are similar in wild-type and TLR4-deficient mice vaccinated with an ISCOMATRIX vaccine (FIGURE 5B). Interestingly though, there is significant overlap in the gene products upregulated by ISCOMATRIX vaccines and those of the TLR response genes. The detail of how the ISCOMATRIX adjuvant activates these TLR-independent innate immune responses remains to be elucidated and is the subject of ongoing experimentation but, as discussed later, may in part be due to the efficiency with which ISCOMATRIX vaccines are taken up and processed by APCs. *In vitro* exposure of human dendritic cells (DCs) to ISCOMATRIX adjuvant alone only weakly upregulated the expression on APCs of the major costimulatory molecule, CD86, or MHC II expression when compared with other agents, such as intact *Escherichia coli* or CD40 ligand [17].

However, these same maturation markers are dramatically upregulated on draining lymph node DCs (to levels similar to those seen with LPS) when ISCOMATRIX adjuvant is administered *in vivo* (FIGURE 6). This suggests that the types of cytokine cascades induced by ISCOMATRIX adjuvant *in vivo* cannot be reproduced *in vitro* and reveals a potentially important application for ISCOMATRIX adjuvant in the immunotherapy of chronic viral infections, such as herpes simplex virus, which downregulates the expression of MHC II.

#### Antigen delivery

To date, there is no evidence that cellular uptake of ISCOMATRIX adjuvant is mediated by specific membrane-bound receptors nor does it appear to bind to, and subsequently activate, APCs via interaction with TLRs (UNPUBLISHED OBSERVATION). However, it is important to keep in

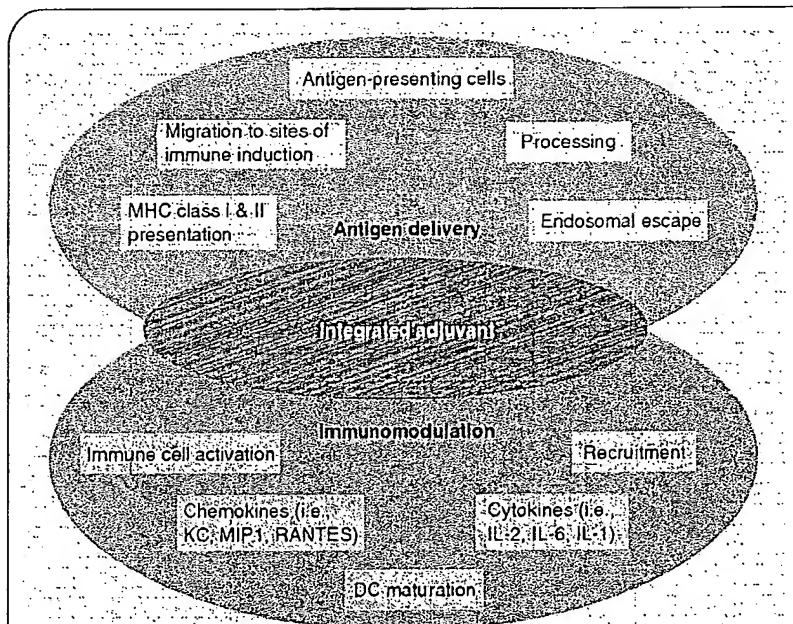
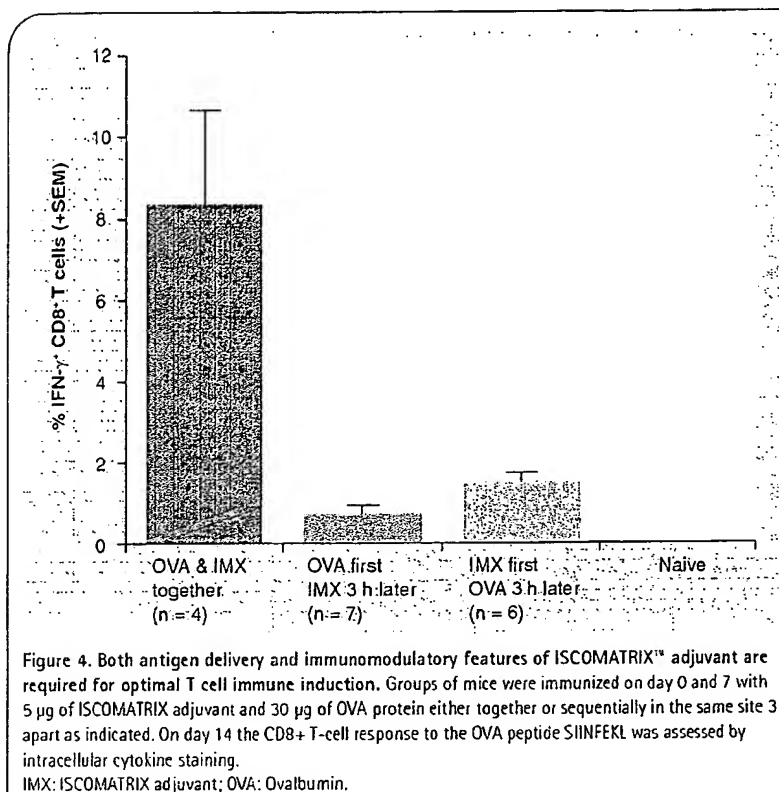


Figure 3. ISCOMATRIX™ adjuvant integrates both antigen delivery and immunomodulatory features.



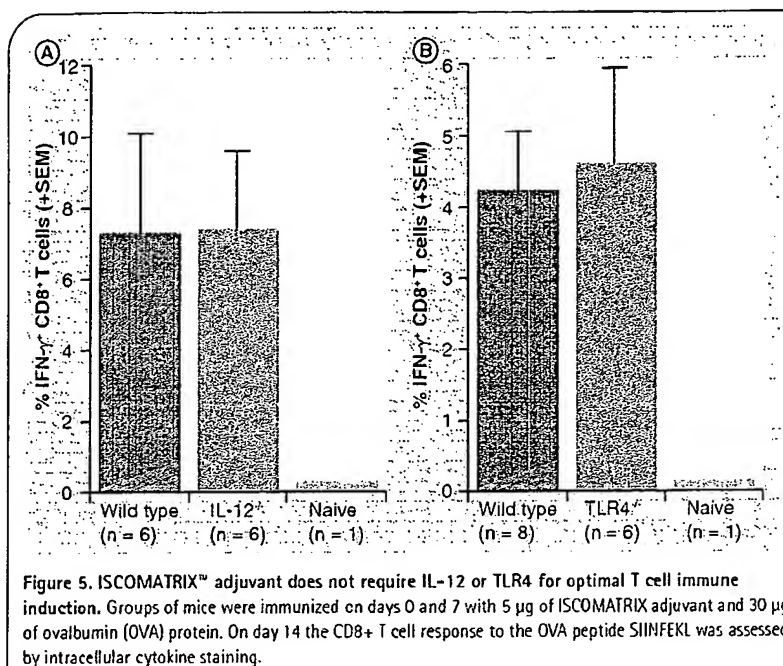
mind that APC activation, although important, is clearly not the only adjuvant property required for the induction of cellular responses. This is particularly true for the induction of CD8<sup>+</sup> T cells, which also requires that antigen is delivered in such a way that it gains access to the MHC I antigen-processing pathway (FIGURE 3A). The possibility that the ISCOMATRIX adjuvant binds to an as yet unidentified receptor cannot be ruled out; however, it appears unlikely. Instead, it is possible that the hydrophobic nature of the ISCOMATRIX adjuvant facilitates its interaction with membranes at the cell surface and with subcellular organelles, such as endosomes, facilitating translocation of antigen into the cytosol. Furthermore, because of its particulate nature, the ISCOMATRIX adjuvant is effectively targeted to, and taken up by, APCs. Being typically 40–50 nm in diameter, ISCOMATRIX adjuvant cage-like structures are similar in size to the viral pathogens that the immune system has evolved to eliminate. Consistent with this, the optimal particle size for inducing CTL responses was in the 40–50 nm range [18]. Once bound to APCs, the antigens in ISCOMATRIX adjuvant are rapidly taken up and processed for both MHC I and MHC II presentation [19].

#### Antigen processing

One of the greatest challenges for the development of subunit vaccines that are capable of inducing CD8<sup>+</sup> CTL responses has been the requirement to deliver antigen to the cytoplasm so that it can gain access to the MHC I processing pathway. The ISCOMATRIX adjuvant achieves this goal and, at the same

time, is able to access MHC II antigen processing. This latter is perhaps not all that surprising, given that this pathway is primarily fed by cellular uptake of exogenous antigens via phagocytosis. The explanation for why ISCOMATRIX adjuvant targets the MHC I pathway so effectively is not immediately obvious, although recent studies in this area have made considerable progress toward providing an answer to this question. Most MHC I-binding peptides are generated in the cytosol as side products of the degradation of misfolded proteins, a process that primarily occurs in the proteasome. A subset of the resulting peptides are translocated across the endoplasmic reticulum (ER) membrane by a dedicated peptide transporter, and then loaded onto peptide-receptive MHC I molecules in the ER and transported to the cell membrane. Robson *et al.* have shown *in vitro* using mouse cells and an OVA ISCOMATRIX vaccine that bone marrow-derived DCs, but not macrophages or naive B cells, prime antigen-specific CD4<sup>+</sup> and CD8<sup>+</sup> T cells [20,21].

Similarly, *in vitro* studies using human cells with an NY-ESO-1 ISCOMATRIX vaccine have shown that only CD1c blood DCs and monocyte-derived DCs are capable of presenting epitopes on both MHC I and MHC II, whereas plasmacytoid DCs are limited to MHC II presentation [19]. Detailed examination of antigen processing of NY-ESO-1 in these human monocyte-derived DCs has shown that for MHC I epitope generation, ISCOMATRIX adjuvant targeted NY-ESO-1 to a fast, proteasome-independent cross-presentation pathway, whereas soluble NY-ESO-1 protein or NY-ESO-1 immune complexes targeted a slow, proteasome-dependent pathway. Both NY-ESO-1 in the form of immune complexes, which are generally regarded as an efficient way to load DCs for MHC I processing [19], and NY-ESO-1 ISCOMATRIX vaccine required active phagocytosis, acidification of endosomal compartments, selective use of lysosomal enzymes, such as calpains and cysteine proteases, and the peptide transporter TAP. Cross-presentation with NY-ESO-1 ISCOMATRIX vaccine, however, occurs largely independently of the traditional proteasome and primarily via tripeptidyl peptidase II [19]. Importantly, DCs pulsed with NY-ESO-1 ISCOMATRIX vaccine exhibited prolonged antigen presentation, which efficiently stimulated NY-ESO-1-specific CD4<sup>+</sup> and CD8<sup>+</sup> T cells for up to 3 days, which was the last timepoint examined in this study. We have been able to show *in vivo* that this prolonged presentation also occurs in the draining lymph node of mice (data not shown). Prolonged presentation such as this increases the potential for productive DC and lymphocyte interactions.



Furthermore, the ability to access different antigen-processing pathways may increase the breadth of peptides and hence the diversity of CD8<sup>+</sup> T-cell response that can be generated in response to ISCOMATRIX vaccines.

#### Immune responses of ISCOMATRIX vaccines in animal models

ISCOMATRIX vaccines have been shown to generate consistently strong humoral and cellular immune responses in an extensive range of animal species including nonhuman primates. The immune responses generated in response to vaccination with ISCOMATRIX vaccines have been reviewed recently [3].

#### Humoral immune responses

Parenteral delivery of ISCOMATRIX vaccines to mice induces a balanced Th1/Th2 cytokine response (i.e., IL-2, IL-4 and IFN-γ) and generates antibodies of all IgG isotypes, including IgG<sub>1</sub> and IgG<sub>2a</sub>. This is a major advantage over aluminum-based vaccines because it mobilizes a broader range of antibody-mediated effector mechanisms, such as complement activation, viral neutralization, antibody-dependent cell-mediated cellular cytotoxicity, opsonization and phagocytosis [3]. This makes the ISCOMATRIX adjuvant suitable for use in prophylactic vaccines where induction of strong, long-lived antibody responses is generally the goal. Studies in several small-animal models and nonhuman primates have demonstrated a major antigen dose-reduction benefit of the ISCOMATRIX adjuvant for parenterally delivered vaccines. This includes a ten- to 100-fold lower antigen dose requirement in guinea pigs for the generation of neutralizing antibody responses against HIV antigen, gp120, when combined with the ISCOMATRIX adjuvant compared with the same antigen formulated with aluminum hydroxide [22]. In addition, ISCOMATRIX vaccines can

achieve acceptable antibody responses with fewer doses than with aluminum-adjuvanted vaccines and the responses generated have increased longevity.

#### Cellular immune responses

##### Chronic viral infections

The induction of high frequency, MHC I-restricted, cytolytic CD8<sup>+</sup> T cells is thought to be crucial to the successful clearance of most chronic viral infections, (e.g. HBV, HCV, HIV and human papillomavirus [HPV]) [23]. However, a significant hurdle for most therapeutic vaccine candidates for human use is the poor induction of MHC I-restricted CD8<sup>+</sup> T cells. Delivery systems, such as DNA and viral vectors, have offered some hope but have potential safety concerns, and in the case of DNA, generally elicit poor CD4<sup>+</sup> and CD8<sup>+</sup> CTL responses. In addition, many of these viral vector strategies induce neutralizing antivector antibodies,

limiting their repeated use. Prime-boost combinations of DNA and live viral vector delivery are currently being evaluated and although results have been promising in animal models, they are yet to be demonstrated convincingly in humans. Several animal models demonstrate ISCOMATRIX vaccines to be potent inducers of both CD4<sup>+</sup> and CD8<sup>+</sup> T-cell responses to a wide variety of antigens, such as naturally occurring immunogens, recombinant proteins, peptides [24] and multiple MHC I epitopes arranged in a linear array, referred to as a POLYTOPE™ vaccine [25]. In a rhesus macaque study, a HCV core ISCOMATRIX vaccine induced strong CD4<sup>+</sup> and CD8<sup>+</sup> T-cell responses against a broad range of epitopes in 100 and 60% of vaccinated animals, respectively [26]. Furthermore, the HCV core ISCOMATRIX vaccine generated long-lived, CD8<sup>+</sup> CTL responses, which were still detectable at a high magnitude almost 1 year after the final dose. Conversely, CTL responses induced with recombinant vaccinia virus expressing HCV core protein were diminished by 4 weeks and negligible by 18 weeks postvaccination. Interestingly, ISCOMATRIX vaccines are also capable of inducing CD8<sup>+</sup> T cells in the absence of CD4<sup>+</sup> T-cell help [12] and CD40 ligation (see later). The mechanisms by which this occurs are not well understood but are the focus of current studies by our group. The capacity to induce a CD8<sup>+</sup> CTL response independent of CD4<sup>+</sup> T-cell help potentially offers an advantage in the settings where CD8<sup>+</sup> T-cell responses are required in a patient population with impaired CD4<sup>+</sup> T-cell function (e.g., chronic viral infections, such as HIV, as well as certain solid cancers).

#### Tumor immunotherapy

As with chronic viral infections, the generation of strong tumor-specific CD8<sup>+</sup> CTL responses are critical if vaccine-based cancer immunotherapy is to be successful. In this

regard, ISCOMATRIX vaccines have been shown to protect mice against subsequent challenge with a variety of tumor models including EG7 (EL4 thymoma cells expressing OVA), B16-OVA, Lewis lung-OVA [12] and B16-NY-ESO-1 [17]. Successful protection in such prophylactic mouse models is an essential prerequisite in the evaluation of vaccine candidates. Although several vaccination strategies have overcome this initial hurdle, few have succeeded in the more challenging therapeutic models, where eradication of established tumor burden is a measure of success. In this regard, a recombinant fusion protein consisting of the E6 and E7 proteins from HPV16 formulated with ISCOMATRIX adjuvant has shown some therapeutic effect in mouse tumor models even after a single immunization (data not shown). In more clinically relevant studies, an ISCOMATRIX vaccine containing the NY-ESO-1 protein (a tumor-associated antigen expressed on a variety of human cancers including melanoma, breast, and colon) [27] has been tested in both mice and human DCs [17]. The NY-ESO-1 ISCOMATRIX vaccine was ingested readily by human monocyte-derived DCs and efficiently processed and presented on both MHC II and MHC I molecules to induce NY-ESO-1-specific CD4<sup>+</sup> and CD8<sup>+</sup> T cells, respectively. This NY-ESO-1 ISCOMATRIX vaccine also induced CD8<sup>+</sup> T cells in HLA-A2 transgenic mice [17], that were capable of recognizing and lysing human HLA-A2<sup>+</sup> NY-ESO-1<sup>+</sup> tumor cells. However, it is probable that successful therapeutic vaccines will not only be required to effectively deliver the tumor antigen to APCs *in vivo* but also provide the necessary conditioning for licensing these APCs and other innate immune response effectors in order to generate the overwhelming tumor-specific T-cell responses needed for eradication of established disease.

#### Clinical trials with ISCOMATRIX vaccines

The optimized ISCOMATRIX adjuvant, in combination with antigen (ISCOMATRIX vaccine), has been studied in seven completed Phase I or II randomized, placebo- or antigen-controlled studies designed to assess safety, tolerability and immunogenicity of the respective vaccines. Intramuscular formulations have been tested in five studies, an intranasal formulation was assessed in one study and pulsed DCs were used in the last. The ISCOMATRIX vaccines tested are part of development programs for either preventative infectious disease indications or therapeutic vaccine programs for infectious diseases or oncology. Within the studies, 198 participants have received at least one dose of an optimized

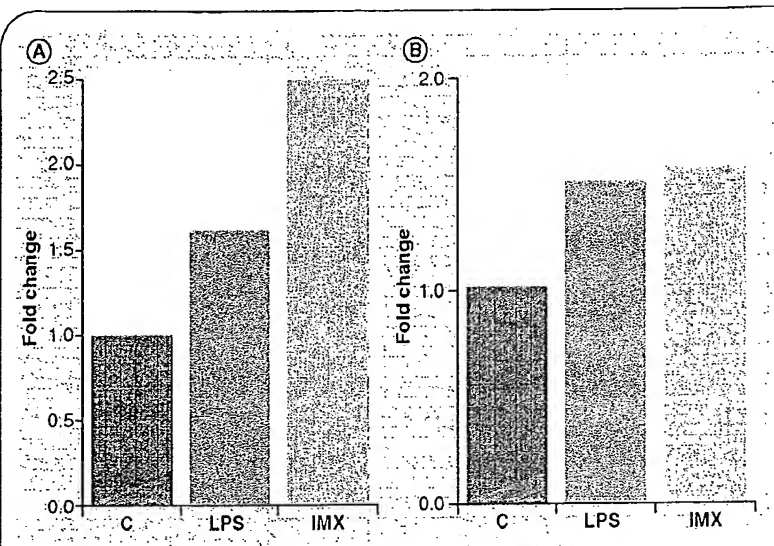


Figure 6. ISCOMATRIX™ adjuvant increases surface expression of markers on dendritic cells *in vivo*. Mice were given 5 µg of LPS or ISCOMATRIX adjuvant subcutaneously and the level of surface expression on dendritic cells in the draining lymph node were determined by flow cytometry. The fold increase in the mean fluorescence intensity of (A) MHC Class II and (B) CD86 markers is shown for CD8 positive conventional dendritic cells.

ISCOMATRIX vaccine. Of these, 70% were healthy volunteers, 4% had cancer, 14% were HIV positive and 12% had chronic HCV infection.

At the time of writing, there are seven ongoing studies with an ISCOMATRIX vaccine. To date, no vaccines containing ISCOMATRIX adjuvant have been licensed by any regulatory agency.

The completed clinical trials are summarized in TABLE 1.

#### Immune responses

The immunogenicity of an ISCOMATRIX vaccine can only be evaluated within the confines of the development program of that vaccine because the immune response is affected by the antigen used, vaccination schedule and study population. The humoral and cellular responses observed with ISCOMATRIX vaccines have previously been described and published [3,28]. In all studies, systemic antibody responses are consistently induced by the ISCOMATRIX vaccine. Analysis of the cellular responses, particularly in the studies assessing the HPV16 E6E7, HCV core protein and NY-ESO-1 antigens, demonstrates that the ISCOMATRIX vaccines induce both antigen-specific CD4<sup>+</sup> and CD8<sup>+</sup> T-cell responses in the majority of study participants.

While the majority of participants in studies to date have been immunocompetent, there are data suggestive that ISCOMATRIX vaccines are able to induce broad cellular responses in immunocompromised subjects as in the study evaluating the NY-ESO-1 antigen in melanoma patients. Several participants who had received a prototype NY-ESO-1 ISCOMATRIX vaccine in one clinical trial were participants in a subsequent NY-ESO-1 ISCOMATRIX vaccine trial several

Table 1. Summary of completed clinical trials with optimized ISCOMATRIX™ vaccines.

Study number	Clinical program (administration)	Study population	Number*	Number of vaccinations	Dose (µg)		Control
					IMX	Antigen	
1	Inactivated influenza vaccine (intramuscular)	Healthy volunteers 60–64 years (n = 110)	55	1	60	15, 45	Commercial influenza vaccine or influenza antigen control
2	HPV16 E6E7 vaccine (intramuscular)	Healthy volunteers 18–45 years (n = 42)	36	3	60, 120	5, 25, 70 240	PBS
3	HPV16 E6E7 vaccine (intramuscular)	HIV positive 18–60 years (n = 35)	28	3	120	25, 70 240	PBS
4	HCV core vaccine (intramuscular)	Healthy volunteers 18–45 years (n = 30)	24	3	120	5, 20, 50	PBS
5	HCV core vaccine (intramuscular)	HCV positive 18–60 years (n = 33)	23	3	120	5, 50	PBS
6	Autologous peripheral blood-derived dendritic cells pulsed with NY-ESO-1 vaccine (intradermal)	Patients with treated cancer and minimal residual disease, over 18 years of age (n = 8)	8	3	120	200	Nil
7	Inactivated influenza vaccine (intranasal)	Healthy volunteers 18–45 years (n = 40)	24	2	100, 500, 1000	30	PBS or commercial influenza vaccine

\*Number of participants receiving ISCOMATRIX vaccines and does not include those who received placebo or antigen control vaccines.  
HPV: Human papillomavirus; IMX: ISCOMATRIX adjuvant; PBS: Phosphate-buffered saline.

years later. When examining their pre-existing T-cell responses to NY-ESO-1 prior to beginning vaccination in the second trial, several of these participants demonstrated a high frequency of MHC I-specific memory CD8<sup>+</sup> T-cell responses to several NY-ESO-1 epitopes 500–800 days after completing the first study. This suggests that ISCOMATRIX vaccines generate prolonged memory T-cell responses, which may be of clear benefit for protection against relapse or reinfection.

There are also promising data from a study evaluating a therapeutic ISCOMATRIX vaccine in 35 HIV-positive participants with a baseline CD4<sup>+</sup> of greater than 300 cells/µl who had anal oncogenic HPV infection detected by PCR. Participants were randomized as four active to one placebo into one of four cohorts with 28 participants, each receiving three doses of vaccine (HPV16 E6E7 antigen with 120 µg ISCOMATRIX adjuvant) and seven receiving placebo (PBS). The first three cohorts evaluated three ascending antigen doses and the fourth evaluated the effect of accelerated dosing schedule at the highest antigen dose. The data suggest that vaccination was effective as antigen specific IgG antibodies were detected in 96.4% of evaluable participants (27/28). IFN-γ responses as assessed by QuantiFERON™-CM1 assay using whole blood stimulated with 5 µg/ml HPV16 E6E7 protein, indicated antigen-specific T-cell activation with approximately 90% (25/28) of evaluable participants responding to active vaccination on at least one postvaccination timepoint. Further detailed evaluation of the immunogenicity data is underway. The vaccine was well tolerated in this

population and there were no dose-limiting toxicities or discontinuations due to vaccine-related adverse events. No vaccine-related serious adverse events occurred.

Thus, in clinical trials, ISCOMATRIX vaccines have been both safe and well tolerated by human patients, as well as being highly immunogenic, generating potent antibody as well as broad-spectrum and long-lived CD4<sup>+</sup> and CD8<sup>+</sup> T-cell effectors. These are all key characteristics required for successful therapeutic vaccines.

#### Safety & tolerability

The safety and tolerability of vaccines containing QS21 have been described [8,29,30]. General concerns with these vaccines have included increased local and systemic reactogenicity and the potential for induction of immunopathologic adverse reactions. In the clinical trials performed to date using the optimized ISCOMATRIX adjuvant, comprehensive evaluations of safety and tolerability have been carried out and the respective ISCOMATRIX vaccines have been found to be safe and tolerable.

To date, no vaccine-related serious adverse events or deaths have been reported in any completed or ongoing studies. With the optimized ISCOMATRIX adjuvant, no participants discontinued due to adverse events. Although a direct comparison with the prototype ISCOMATRIX adjuvant was not performed, it is interesting to note in studies in which 774 participants were administered prototype adjuvant, 15 withdrew from their

Table 2. Number of participants with solicited and unsolicited injection-site adverse events by maximum intensity reported at any timepoint in the integrated safety population.

Treatment group*	Maximum intensity of adverse experience n (%)				Overall* n (%)
	None	Mild (grade 1)	Moderate (grade 2)	Severe (grade 3)	
<i>Inactivated split-virion influenza vaccine single vaccination study*</i>					
0 µg IMX, antigen control (n = 55)	30 (55%)	19 (35%)	4 (7%)	2 (4%)	25 (45%)
60 µg IMX + influenza antigen, (n = 55)	9 (16%)	32 (58%)	13 (24%)	1 (2%)	46 (84%)
<i>HPV16 E6E7 and HCV core three-vaccination studies combined<sup>§</sup></i>					
0 µg IMX, placebo saline control, n = 12	4 (33%)	7 (58%)	1 (8%)	0 (0%)	8 (67%)
60 µg IMX + HPV E6E7 antigen, postvaccination, 1, n = 12	0 (0%)	5 (42%)	3 (25%)	4 (33%)	12 (100%)
120 µg IMX + HPV E6E7 or HCV core antigen, postvaccination 1, n = 48	1 (2%)	16 (33%)	16 (33%)	15 (31%)	47 (98%)
60 µg IMX + HPV E6E7 antigen all doses, n = 12	0 (0%)	2 (17%)	1 (8%)	9 (75%)	12 (100%)
120 µg IMX + HPV E6E7 or HCV core antigen, all doses, n = 48	0 (0%)	4 (8%)	18 (38%)	26 (54%)	48 (100%)

\*Grade 1, 2 or 3 intensity.  
\*TABLE 1, study 1.  
<sup>§</sup>HPV16 E6E7 antigen was administered with either 60 or 120 µg IMX. HCV core antigen was only administered with 120 µg IMX. Data for HPV16 E6E7 antigen and HCV Core antigen administered with 120 µg IMX have been combined for the purposes of this analysis (TABLE 1, studies 2 and 4, respectively).  
HPV: Human papillomavirus; IMX: ISCOMATRIX adjuvant.

\*Grade 1, 2 or 3 intensity.

\*TABLE 1, study 1.

<sup>§</sup>HPV16 E6E7 antigen was administered with either 60 or 120 µg IMX. HCV core antigen was only administered with 120 µg IMX. Data for HPV16 E6E7 antigen and HCV Core antigen administered with 120 µg IMX have been combined for the purposes of this analysis (TABLE 1, studies 2 and 4, respectively).

HPV: Human papillomavirus; IMX: ISCOMATRIX adjuvant.

respective study or required early termination of the vaccination schedule or dose reduction due to an adverse event. This suggests that the optimized ISCOMATRIX adjuvant is better tolerated.

A comparison of safety data from three of the seven completed clinical studies provides insight to the safety profile. These three were designed as Phase I safety studies in healthy volunteers to assess the safety and tolerability of the respective ISCOMATRIX vaccines using optimized ISCOMATRIX adjuvant as an intramuscular formulation. Adverse event data were collected and analyzed in a consistent manner across the three studies. Only one serious adverse event, in a participant randomized to ISCOMATRIX adjuvant, was reported. This event was not considered vaccine related.

TABLES 2 & 3 reflect the number of participants with injection site or systemic adverse events experienced at any timepoint in these three studies. In all three studies solicited injection-site reactogenicity included pain, redness and swelling. Severe events were classified as pain limiting normal activity, redness of greater than 50 mm or swelling of greater than 50 mm. Systemic symptoms included fever, headache, myalgia, chills, sweating, nausea, vomiting and fatigue, which were considered severe if participants were unable to work or do usual activity.

In the influenza study (TABLE 1), which was not powered to detect differences in reactogenicity between adjuvant vaccine and the antigen comparators, a trend for a higher proportion of participants receiving adjuvant to experience injection site and systemic adverse events compared with antigen alone was noted. The ISCOMATRIX vaccine and the antigen controls were well

tolerated and of those reporting symptoms, in all treatment groups, the majority reported mild injection site and systemic events. Notably the adjuvant did not increase the propensity for severe injection-site reactions or severe systemic events.

In both the HPV16 E6E7 and HCV core protein studies (TABLE 1) a three-dose vaccination regimen was used. Comparisons were made of reactogenicity post the first vaccination and after all three vaccinations. Consistent with other studies, pain was the most commonly reported injection site event reported.

In these two studies, more participants experienced a severe reaction after one vaccination as compared with the influenza study. The severe events were mostly redness and swelling, rather than pain (data not shown), and may have been due to formulation differences as the HPV16 E6E7 vaccine contained urea, which is known to be a local irritant. There was no apparent effect of adjuvant dose on the proportion of participants reporting an injection-site event following administration of the first vaccination.

Systemic events were mostly mild to moderate in intensity and there was no apparent effect of ISCOMATRIX adjuvant dose on the systemic profile in this data series. The most common systemic events reported were self-limiting myalgia and fatigue.

A higher proportion of subjects experienced a severe injection site or systemic event after exposure to three vaccinations. A review of the data revealed this was due to increased opportunity for an event with three exposures and was not due to an accumulative reactogenicity with each subsequent exposure.

In a *post hoc* analysis of the three studies, adverse events of special interest, suggestive of allergic phenomena, were clustered to assess for any evidence of immunopathologic events. No safety signal was evident and no events suggestive of anaphylaxis or an allergic syndrome were reported.

Exploratory assessment of serum markers of autoimmunity, inflammation and allergy from the two multivaccination studies using HPV16 E6E7 and HCV core protein was undertaken. Of note, an onset of positive anticardiolipin antibodies was noted in 0% of placebo and 6% of adjuvant recipients. The significance of this is unclear as this is a nonspecific marker of autoimmunity and can be confounded by concurrent infection. It is possible that an upper respiratory infection experienced by a number of participants may have been the cause. The more sensitive marker anti-B2 glycoprotein 1 was also tested for and was negative in all participants. Of interest, raised IgE, generally twofold or less over baseline, was noted in 3.6% of participants compared with 8% receiving placebo. None of these participants reported adverse events suggestive of allergy or had raised eosinophil counts.

Minor fluctuations in all laboratory parameters do occur after exposure to ISCOMATRIX adjuvant with or without antigen compared with placebo. However, there does not appear to be a clinically relevant difference in the incidence of laboratory abnormalities where comparisons with an antigen control arm are available.

Of note in this data series, mild transient decreases in platelet counts between 125 and 140 × 10<sup>9</sup>/l which were not considered clinically significant were noted in two participants, both of

whom received 120 µg ISCOMATRIX adjuvant (with antigen). Similar changes were not noticed with 60 µg, antigen control or placebo. In earlier studies using a prototype formulation of adjuvant, there were two incidences of significant thrombocytopenia although the participants remained clinically asymptomatic and their platelet counts spontaneously improved.

Mild changes occurring in liver transaminases and total bilirubin have been noted which appear to occur more frequently after exposure to the higher dose of 120 µg ISCOMATRIX adjuvant compared with placebo. A similar incidence of such abnormalities has been noted when influenza antigen has been used as control.

The relevance of these as markers of possible safety concern remains unclear and CSL continues to monitor all laboratory parameters in its clinical programs.

#### Expert commentary & five-year view

To date, very few vaccine adjuvants have been used in registered human vaccines and, in fact, only aluminium adjuvants are used widely. Aluminium adjuvants have proven effective for the induction of humoral immune responses with vaccine antigens that in and of themselves are relatively immunogenic. The advent of recombinant DNA technology has allowed the development of specific antigens for use in vaccines, which ensure products are better defined and, in some cases, permit their production for the first time. This can lead to improved characterization and safety of products due to lack of potentially virulent or carcinogenic components and reduction of impurities. The

Table 3. Number of participants with solicited and unsolicited systemic reactions by maximum intensity reported at any timepoint in the integrated safety population.

Treatment group	Maximum intensity				Overall* n (%)
	None	Mild(Grade 1)	Moderate (Grade 2)	Severe (Grade 3)	
<i>Inactivated split-virion influenza vaccine single vaccination study**</i>					
0 µg IMX, antigen control, n = 55	14 (26%)	25 (46%)	10 (18%)	6 (11%)	41 (75%)
60 µg IMX + influenza antigen, n = 55	4 (7%)	34 (62%)	12 (22%)	5 (9%)	51 (93%)
<i>HPV16 E6E7 and HCV core three-vaccination studies combined<sup>‡</sup></i>					
0 µg IMX, placebo saline control, n = 12	0 (0%)	6 (50%)	4 (33%)	2 (17%)	12 (100%)
60 µg IMX + HPV E6E7 antigen, postvaccination, 1, n = 12	0 (0%)	6 (50%)	5 (42%)	1 (8%)	12 (100%)
120 µg IMX + HPV E6E7 or HCV core antigen, postvaccination 1, n = 48	4 (8%)	21 (44%)	15 (31%)	8 (17%)	44 (92%)
60 µg IMX + HPV E6E7 antigen all doses, = 12	0 (0%)	3 (25%)	7 (58%)	2 (17%)	12 (100%)
120 µg IMX + HPV E6E7 or HCV core antigen, all doses, n = 48	0 (0%)	4 (8%)	24 (50%)	20 (42%)	48 (100%)

\*Grade 1, 2 or 3 intensity.

\*\*TABLE 1, study 1.

<sup>‡</sup>HPV16 E6E7 antigen was administered with either 60 or 120 µg IMX. HCV antigen was only administered with 120 µg IMX. Data for HPV16 E6E7 antigen and HCV antigen administered with 120 µg IMX have been combined for the purposes of this analysis. (TABLE 1, studies 2 and 4, respectively).

HPV: Human papillomavirus; IMX: ISCOMATRIX adjuvant.

downside, however, is that these antigens are often not very immunogenic and, therefore, require better adjuvants to be effectively used in vaccines. Therefore, there is clearly a need for novel adjuvants and the ISCOMATRIX adjuvant has the features and properties required to be one of the adjuvants used in both prophylactic and therapeutic human vaccines of the future.

To date, there are no vaccines with ISCOMATRIX adjuvant registered for use in humans, although there are a number of effective veterinary vaccines licensed using saponin-based adjuvants using similar technologies. In the human vaccine field, saponin-based adjuvants are in Phase III studies and ISCOMATRIX vaccines have advanced to Phase II studies. The optimized ISCOMATRIX adjuvant is highly characterized, is able to be produced reproducibly at commercial scale and has displayed an excellent immunogenicity and safety profile in clinical trials. As a result, we would expect that either CSL or one of its commercial partners will progress an ISCOMATRIX vaccine to registration within the next 5 years.

Over the next few years, we plan to understand more fully the mechanism of action of the ISCOMATRIX adjuvant, which may lead to a greater understanding of ways to maximize opportunities for the safe and effective use of this vaccine adjuvant. Another area of keen interest is to combine ISCOMATRIX adjuvant with other adjuvants for situations where one mechanism is not sufficient to induce the required immune response, such as in cancer immunotherapy. Studies have already shown that combining ISCOMATRIX adjuvant with oligonucleotide sequences significantly enhance the induction of cytokines, such as IFN- $\gamma$ , which in turn contribute to induction of both innate and specific immune responses. Further studies are required to understand the effects of combining adjuvants but it is possible that over the ensuing years,

knowledge will be sufficient to be able to rationally design not only antigens but also adjuvants to give the desired immune response. The ISCOMATRIX adjuvant will be an integral component in the development of novel human vaccines and either alone or in combination with other adjuvants will facilitate manipulation of the body's own immune system to prevent and/or treat diseases that to date have been refractory to vaccination.

#### Acknowledgements

The authors acknowledge Gina Kanesoulis for her valuable assistance in preparing the manuscript. The authors are also grateful for the valuable contribution of their colleagues at CSL, in particular Nick Wilson, Denise Airey and Nina Kennet, as well as academic and industry partners for their interest and scientific endeavors directed towards better defining our understanding of ISCOMATRIX adjuvant, the manufacturing process, and progressing the clinical development of ISCOMATRIX vaccines. We would also like to acknowledge Ross Hamilton and Alex Hyatt for the cryoelectron micrograph. Thanks also go to John Cox for critical review of the manuscript. ISCOMATRIX and ISCOPREP are trademarks of ISCOTEC AB, a CSL company.

#### Financial & competing interests disclosure

*All authors are employees of CSL. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.*

*Writing assistance was utilized in the production of this manuscript. This was funded by CSL as part of DD budget.*

#### Key issues

- The optimized ISCOMATRIX™ adjuvant is suitable for use in licensed human vaccines.
- ISCOMATRIX adjuvant is very stable and can be formulated with antigen in a variety of ways to produce ISCOMATRIX vaccines.
- Immune responses induced by ISCOMATRIX vaccines include broad antibody responses as well as both CD4<sup>+</sup> and CD8<sup>+</sup> T-cell responses.
- ISCOMATRIX adjuvant stimulates innate immune responses and is very efficient at antigen delivery to both the class I- and class II-processing pathways.
- ISCOMATRIX vaccines are safe and generally well tolerated in humans.

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• of interest

•• of considerable interest

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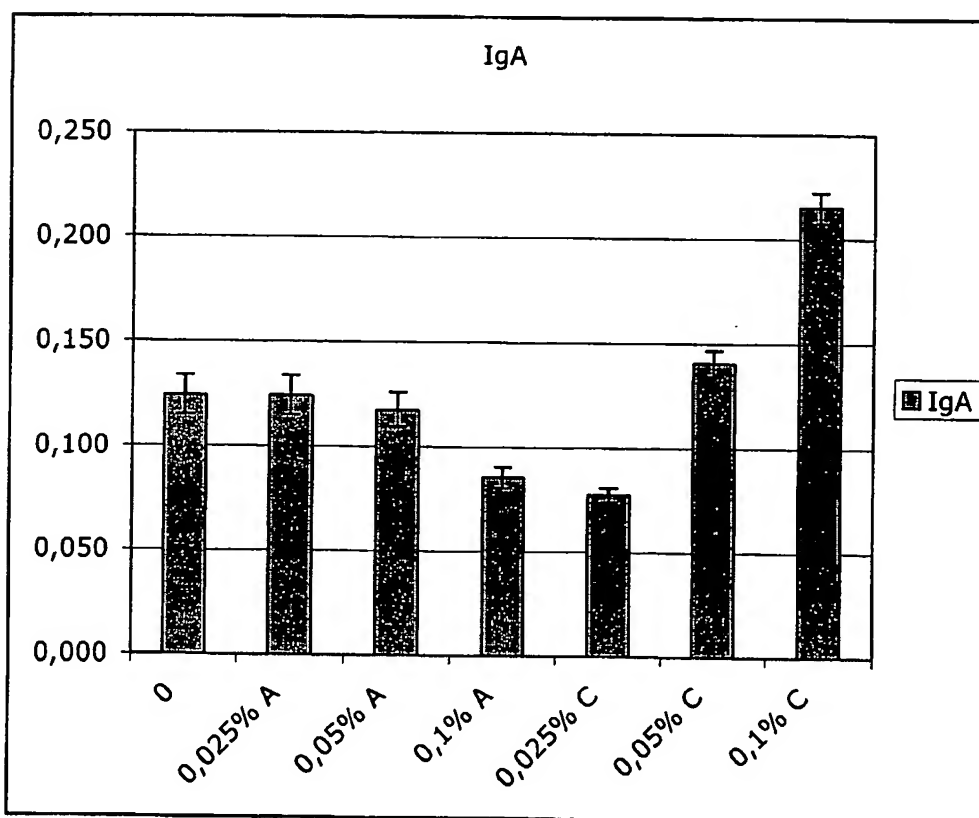
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### Attachment 1

Intranasal administration of PR8 micellers (3 ug) with and without addition of Fraction-A or Fraction-C i free form

0	3 ug PR8 alone
0,025% A	3 ug PR8 + 0,025% Fraction-A
0,050% A	3 ug PR8 + 0,050% Fraction-A
0,100 %A	3 ug PR8 + 0,100% Fraction-A
0,025% C	3 ug PR8 + 0,025% Fraction-C
0,050% C	3 ug PR8 + 0,050% Fraction-C
0,100 %C	3 ug PR8 + 0,100% Fraction-C



# United States Patent [19]

Kensil et al.

[11] Patent Number: 5,057,540

[45] Date of Patent: Oct. 15, 1991

## [54] SAPONIN ADJUVANT

[75] Inventors: Charlotte A. Kensil, Milford; Dante J. Marciani, Hopkinton, both of Mass.

[73] Assignee: Cambridge Biotech Corporation, Worcester, Mass.

[21] Appl. No.: 573,268

[22] Filed: Aug. 27, 1990

### Related U.S. Application Data

[63] Continuation of Ser. No. 200,754, May 31, 1988, abandoned, which is a continuation-in-part of Ser. No. 55,229, May 29, 1987, abandoned.

[51] Int. Cl.<sup>5</sup> ..... A61K 31/70; A61K 31/705; A61K 39/00

[52] U.S. Cl. .... 514/25; 514/26; 514/33; 514/35; 514/885; 424/88; 424/195.1; 536/4.1; 536/6.3; 536/5

[58] Field of Search ..... 514/25, 26, 33, 35, 514/885; 424/88, 89, 195.1; 536/4.1, 6.3, 18.1, 127, 128, 5

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Primary Examiner—Ronald W. Griffin

Assistant Examiner—Nancy S. Carson

Attorney, Agent, or Firm—Sterne, Kessler, Goldstein & Fox

### [57] ABSTRACT

Substantially pure saponins are disclosed. The saponins of the present invention are useful as immune adjuvants. Disclosed as well are immune response-provoking compositions comprising an antigen in admixture with the substantially pure saponins.

16 Claims, 23 Drawing Sheets

Figure 1

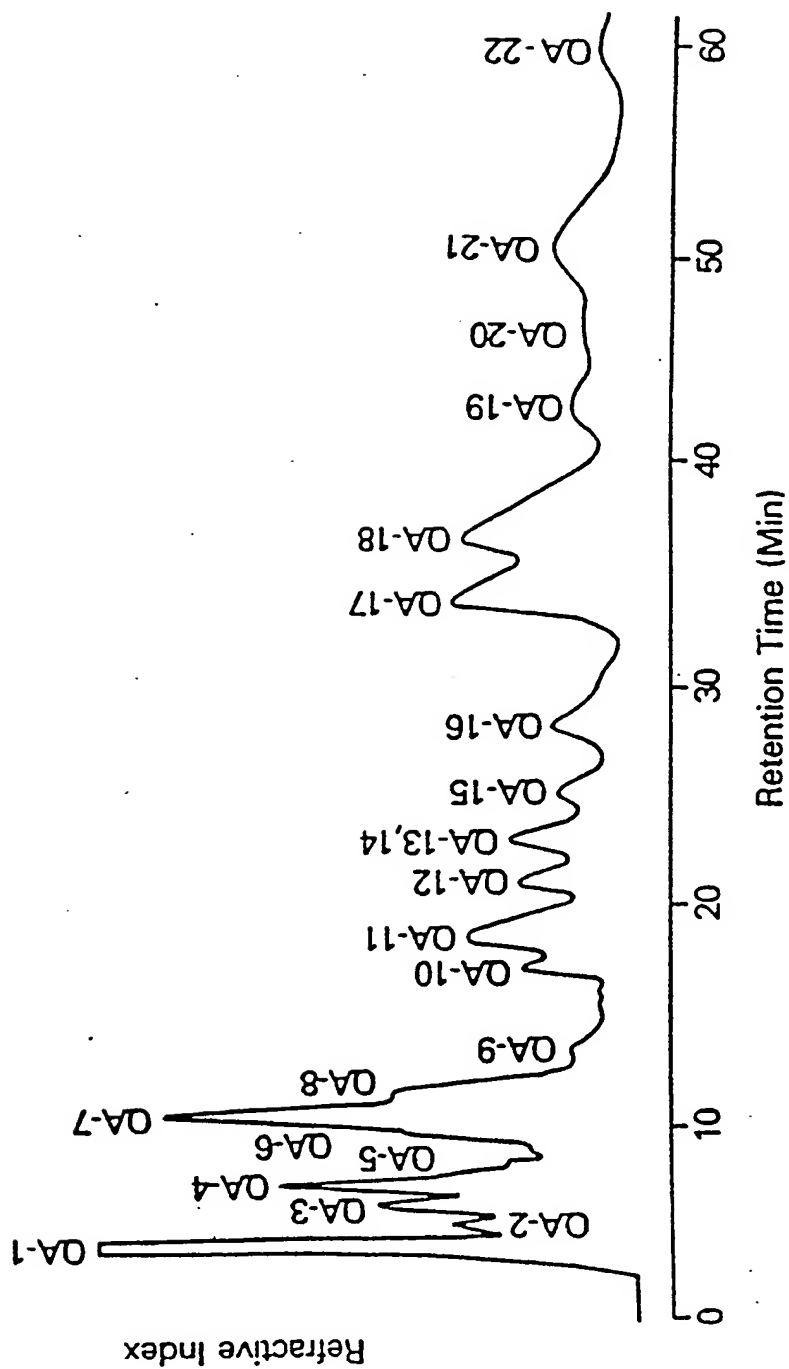


Figure 2

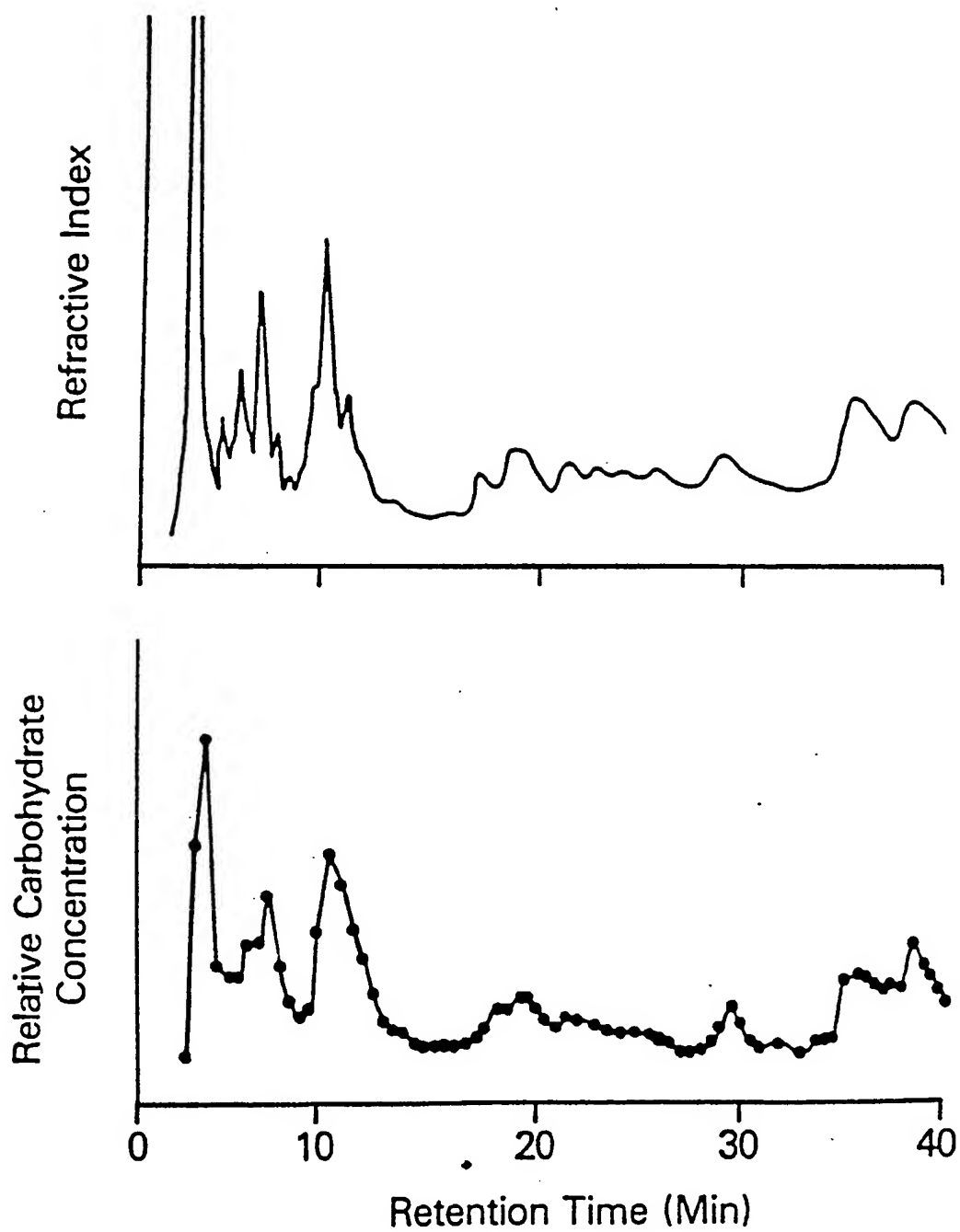


Figure 3

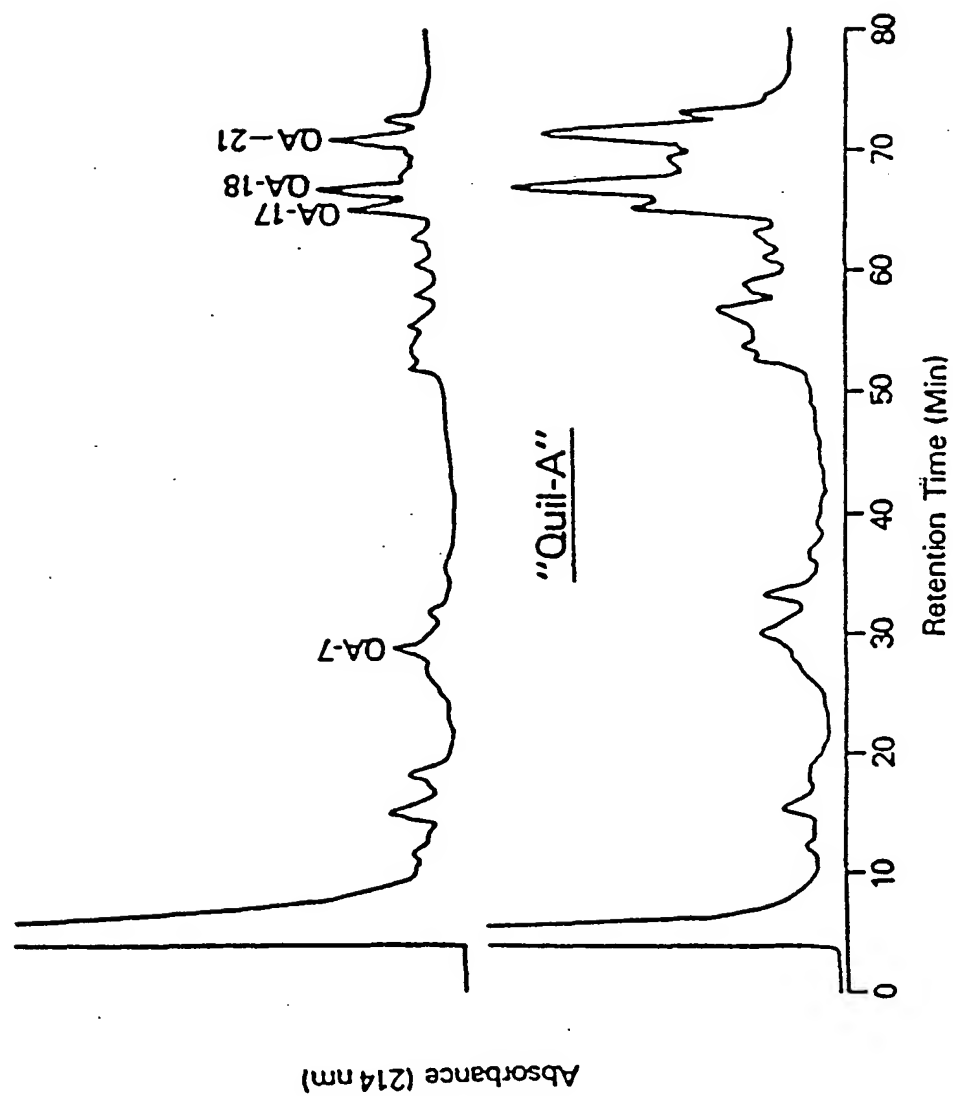


Figure 4A

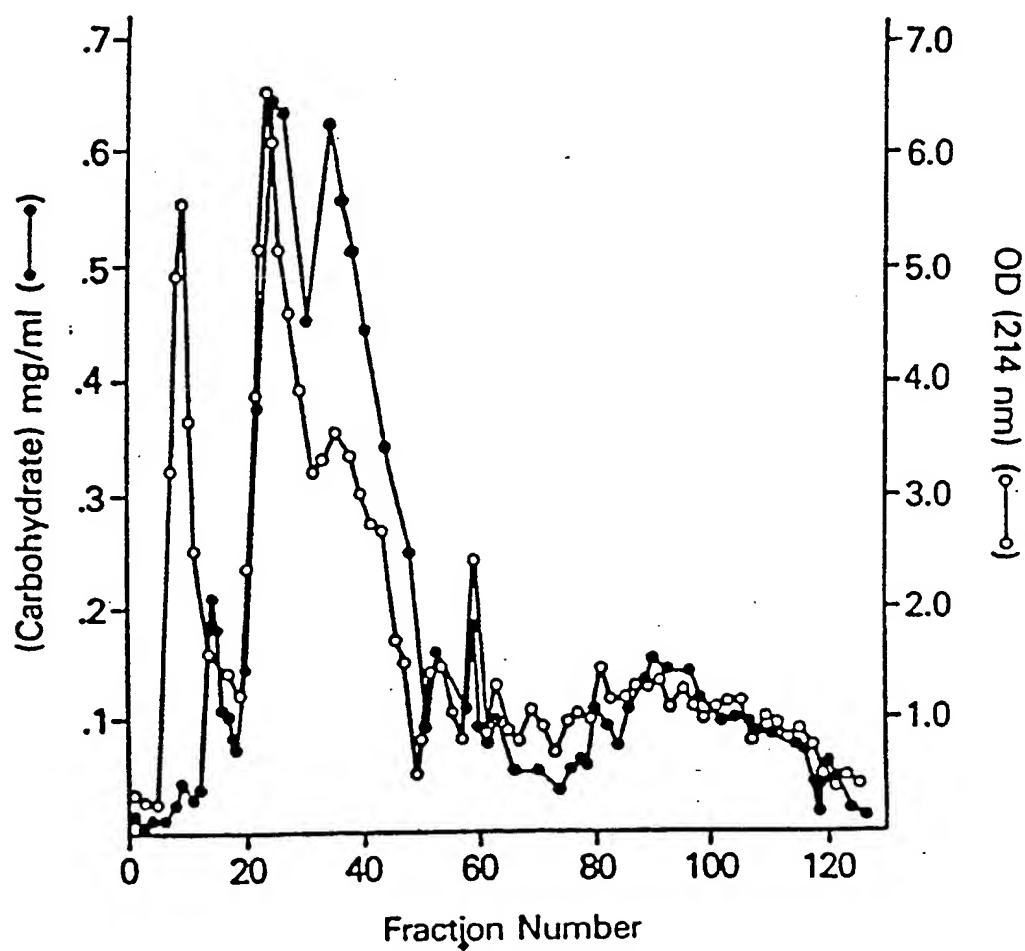


Figure 4B

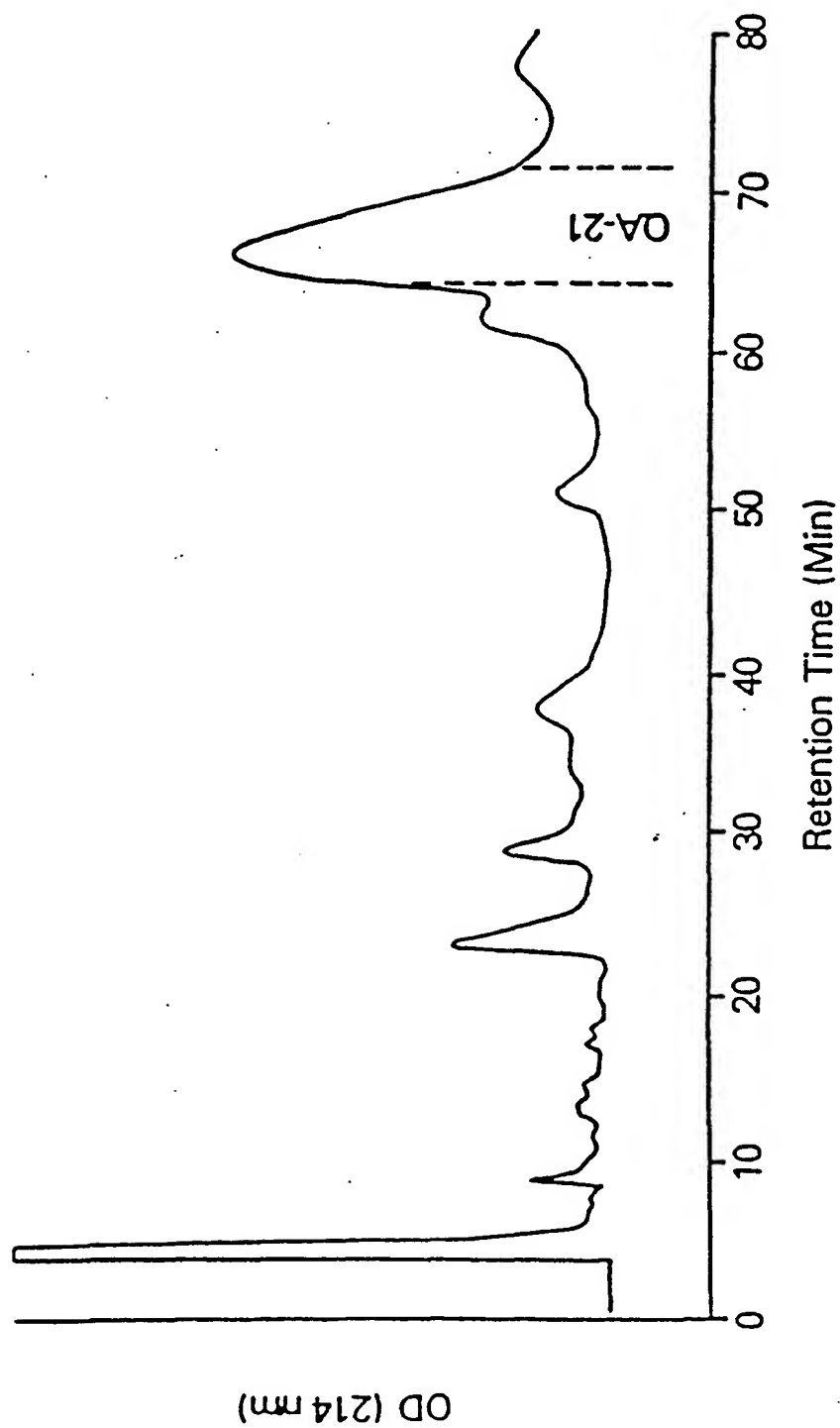


Figure 4C

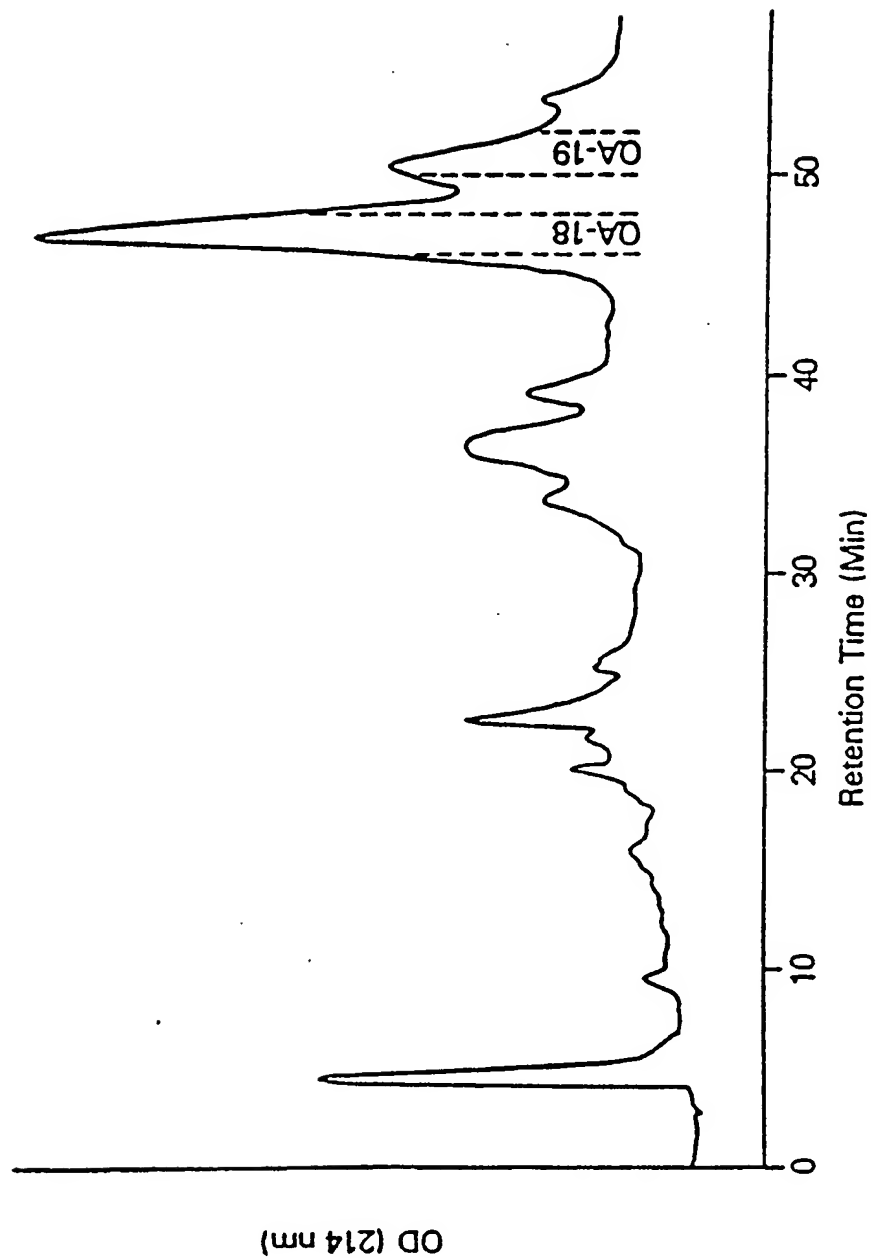
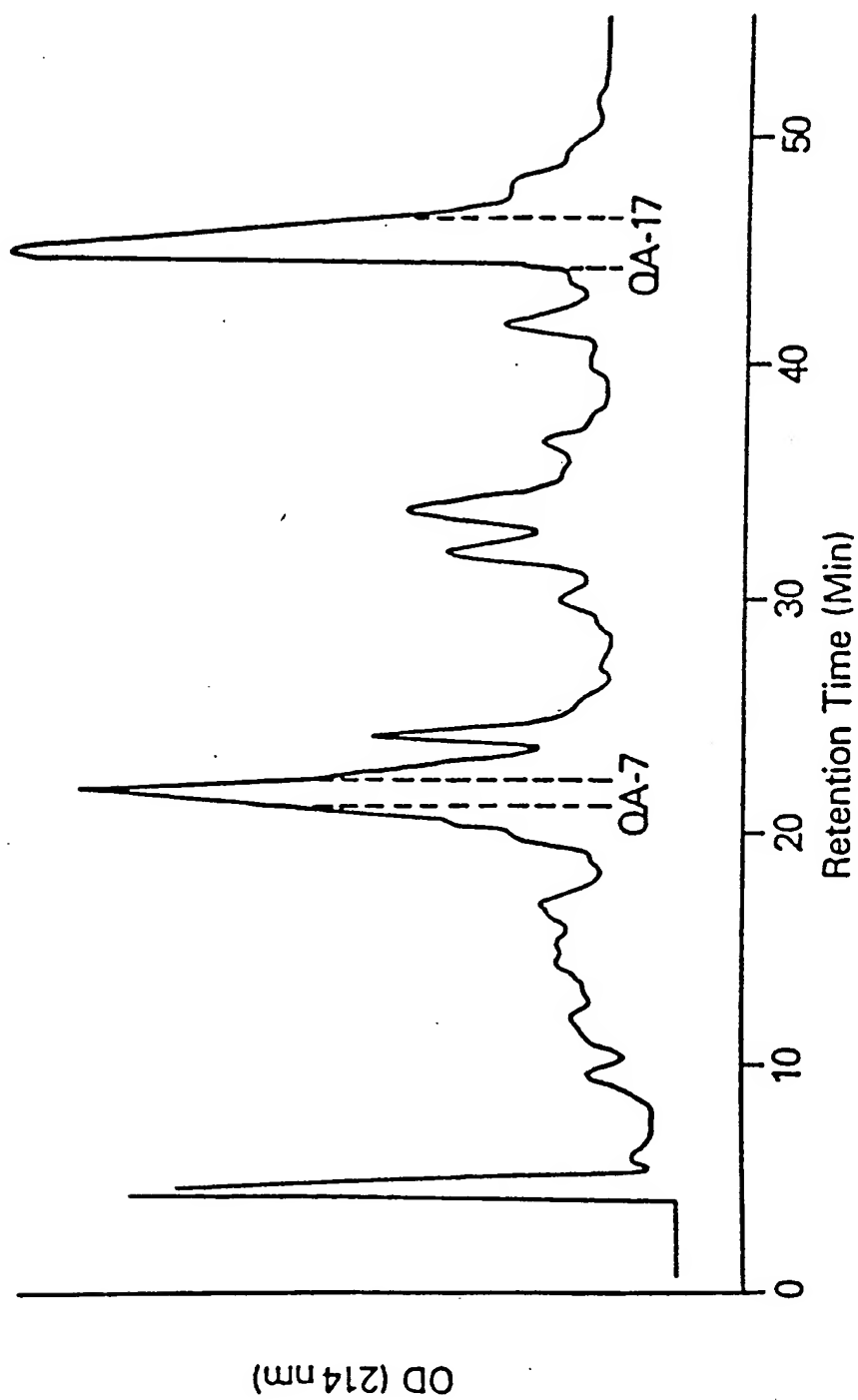


Figure 4D



## REVERSE PHASE TLC

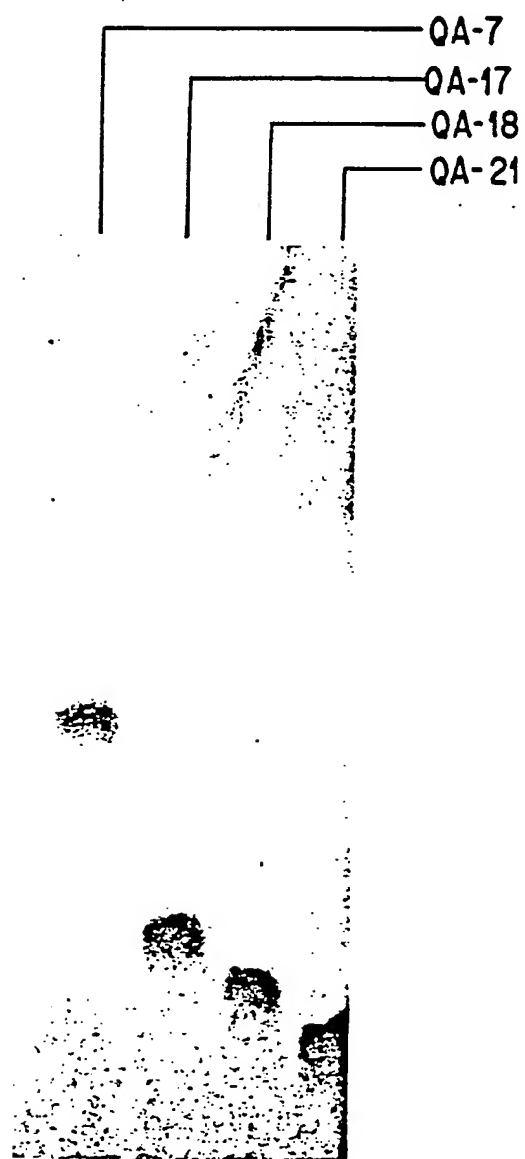


FIG. 5A

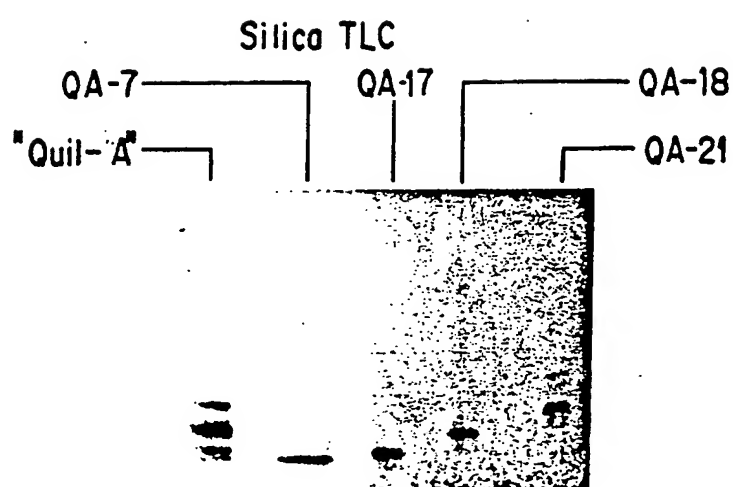


FIG. 5B

Figure 6

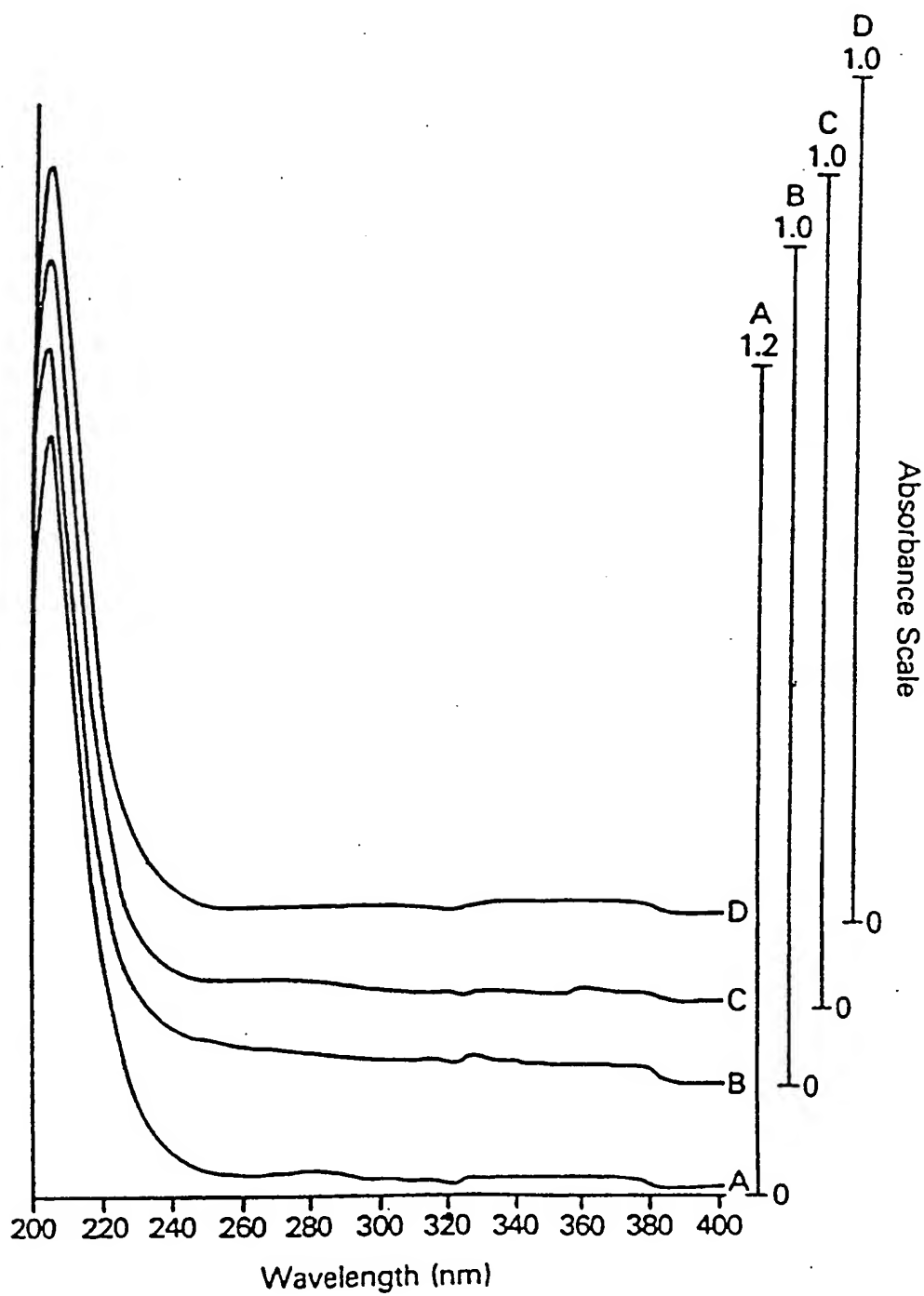


Figure 7A

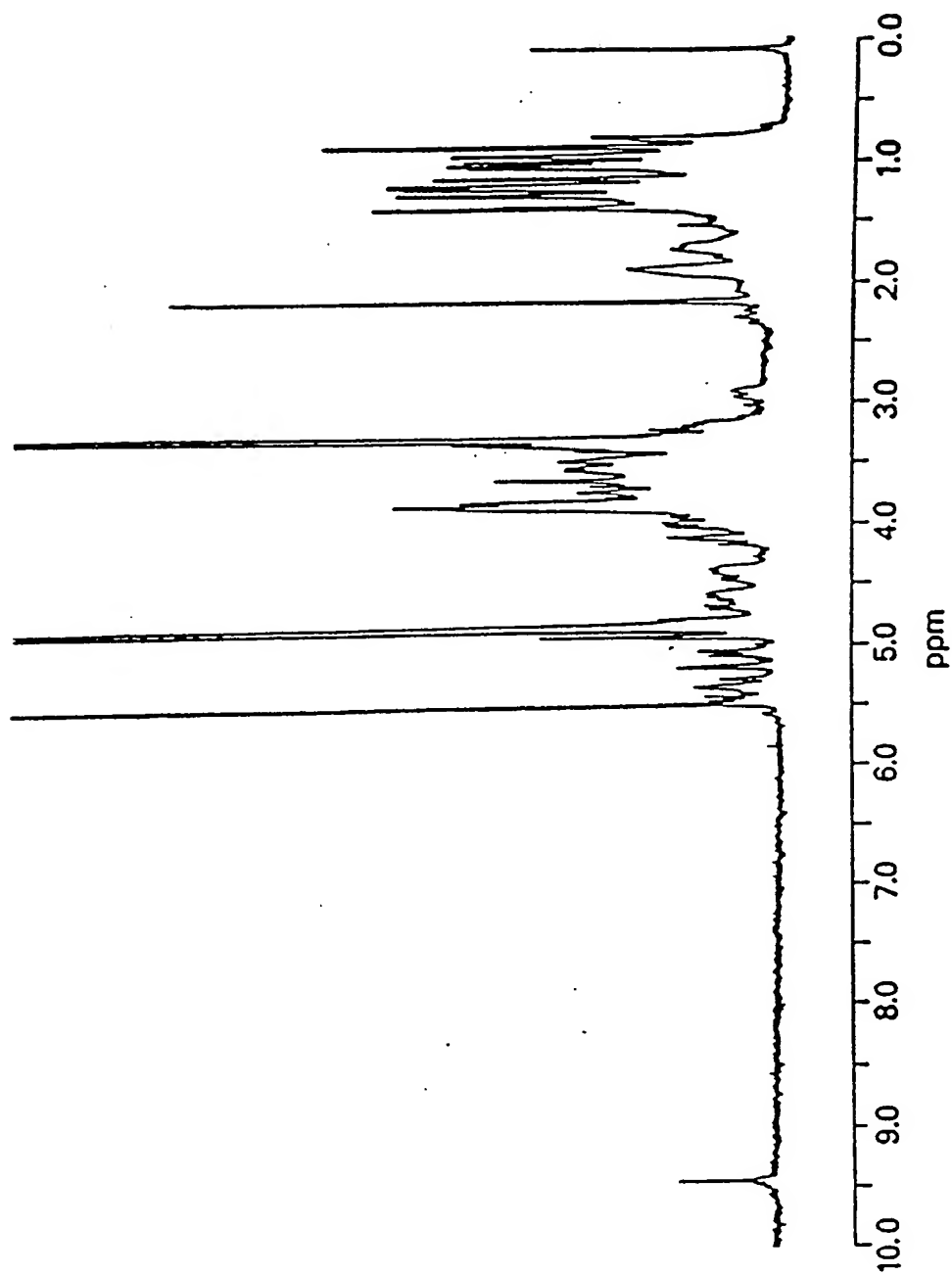


Figure 7B

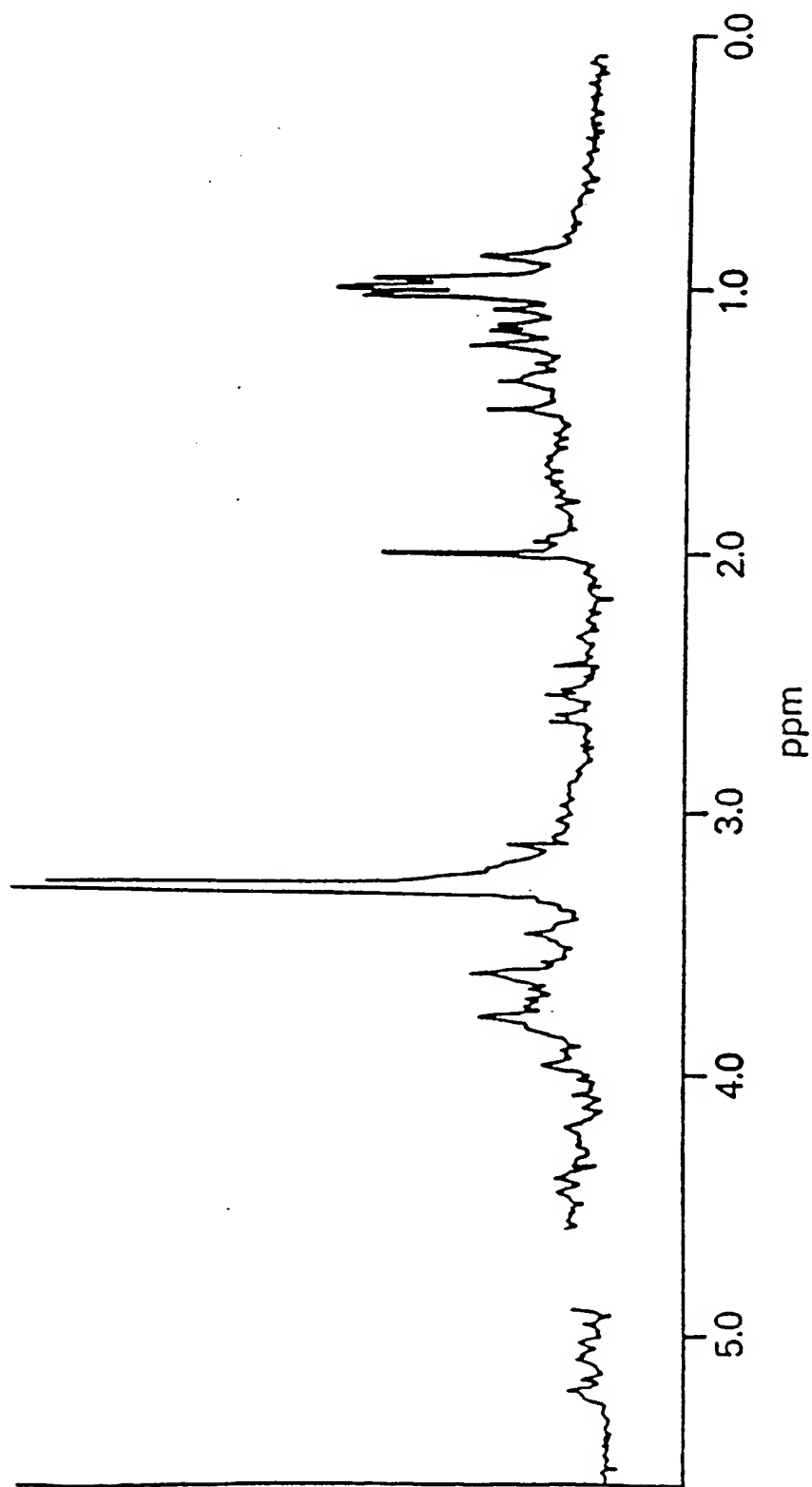


Figure 7C

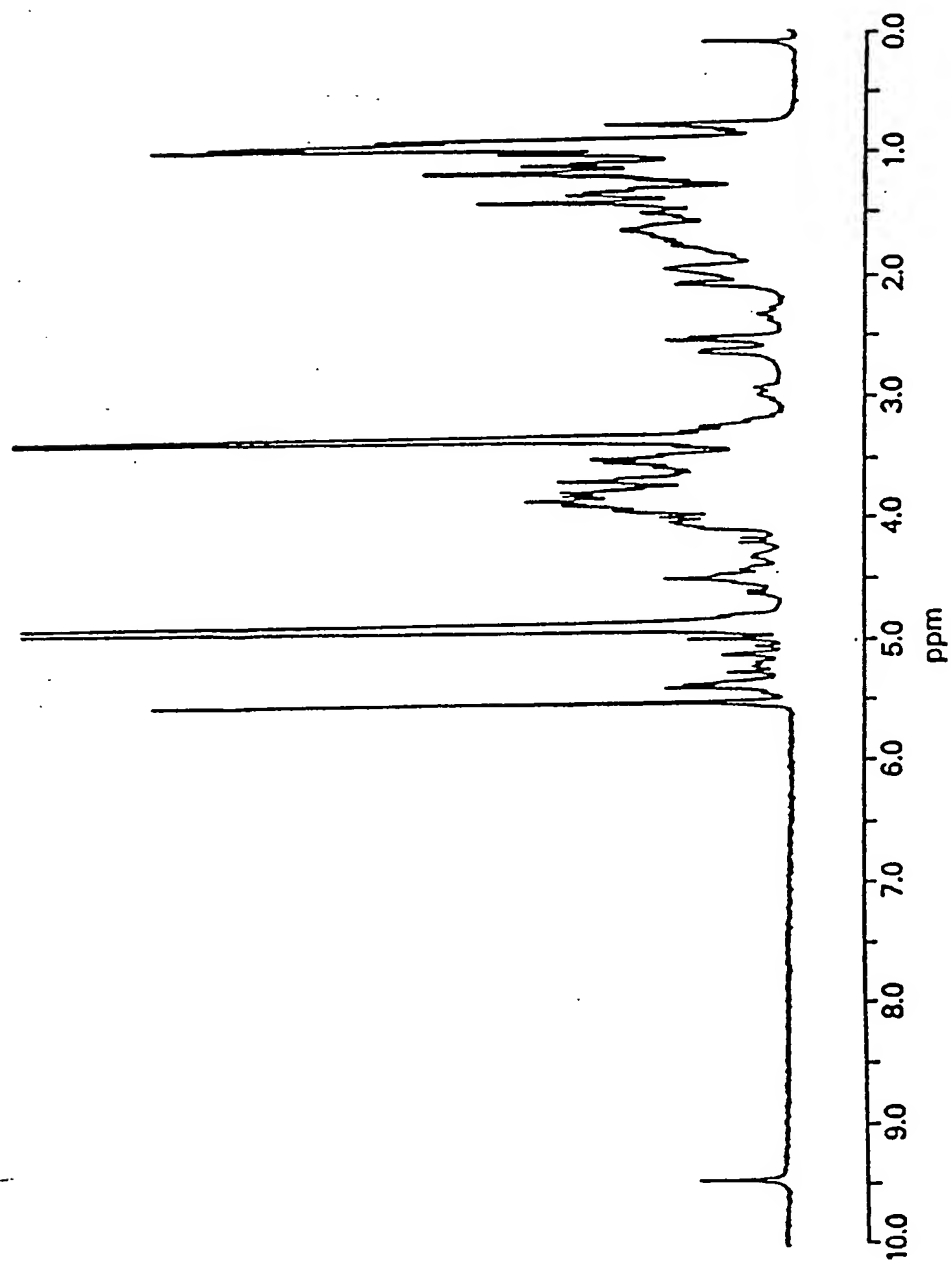


Figure 8A

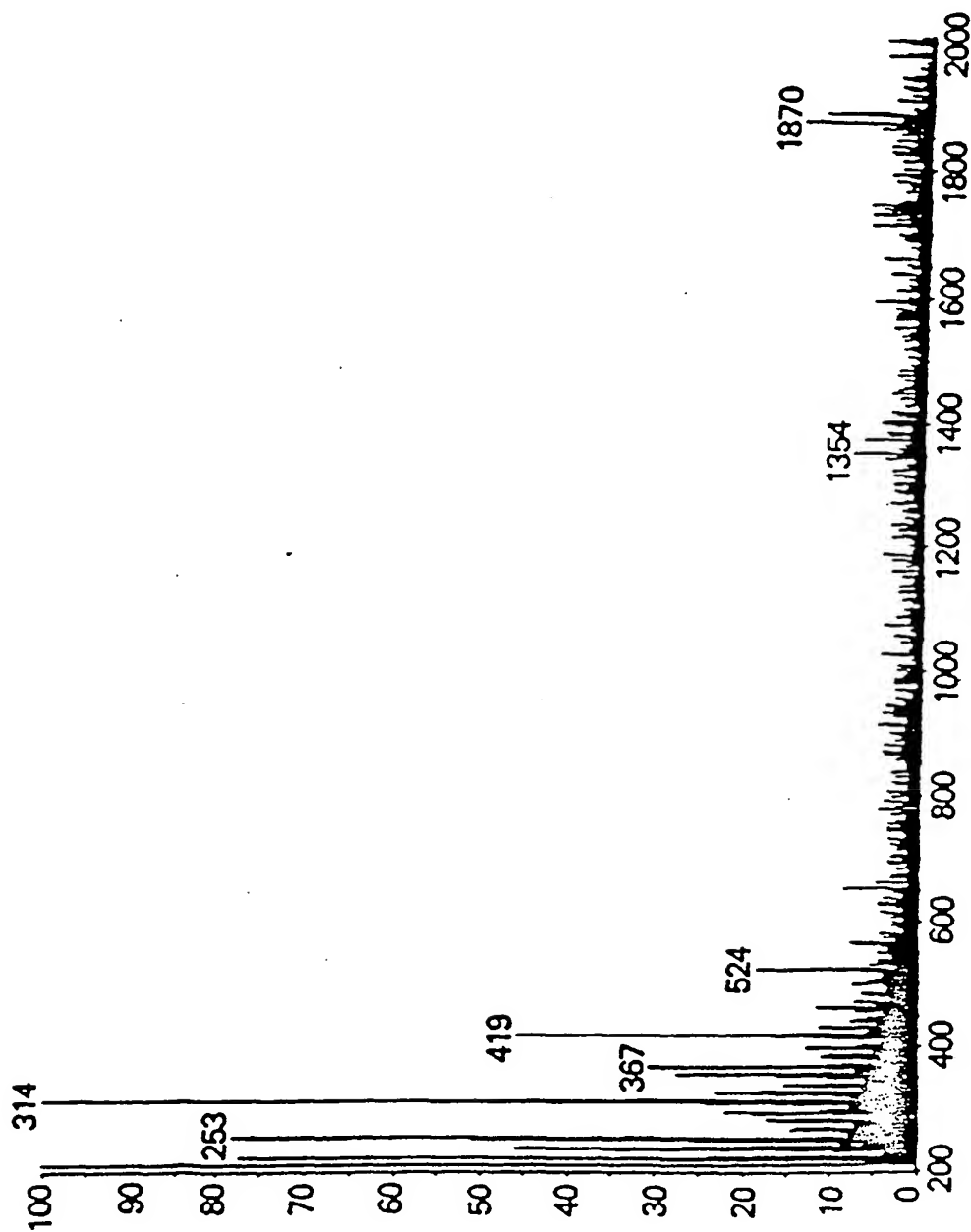


Figure 8B

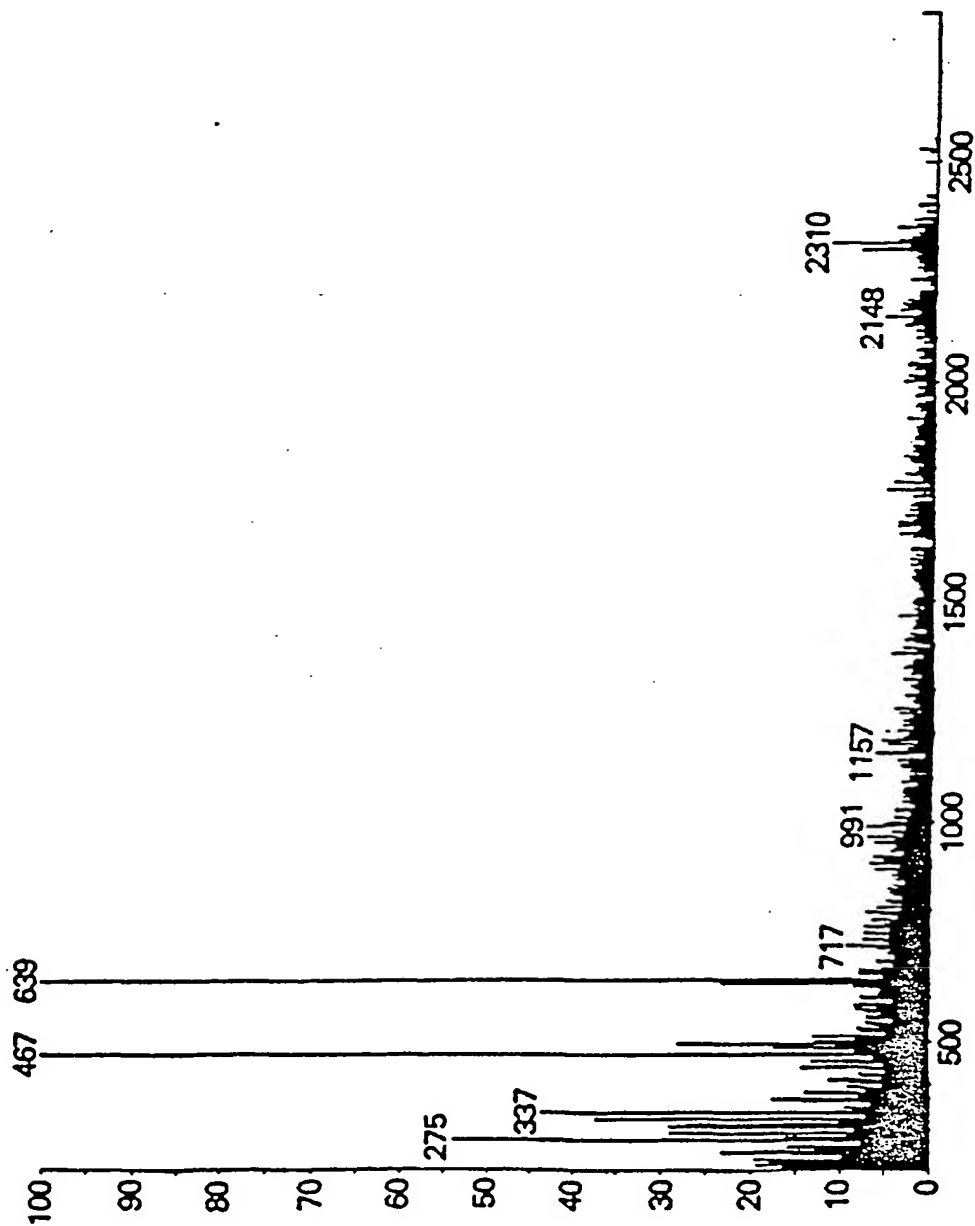


Figure 8C

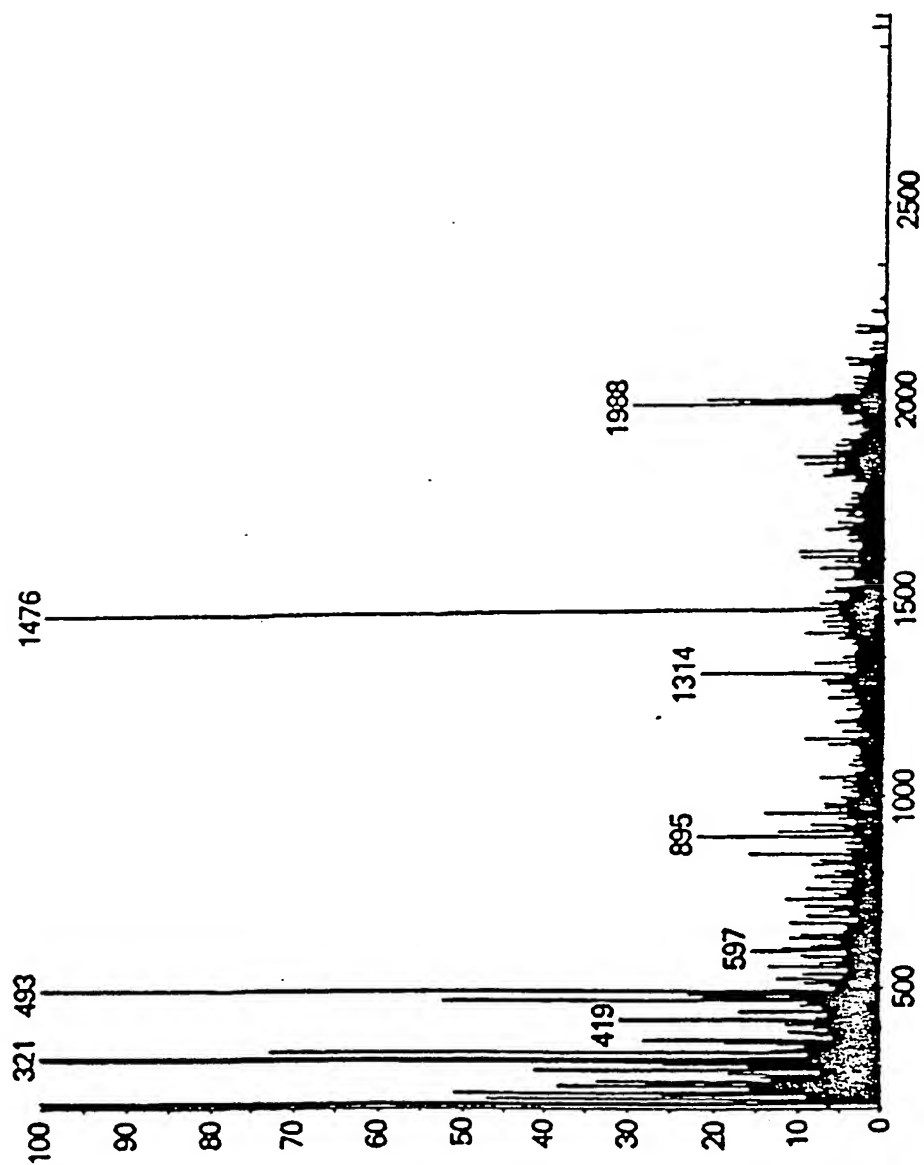


Figure 9

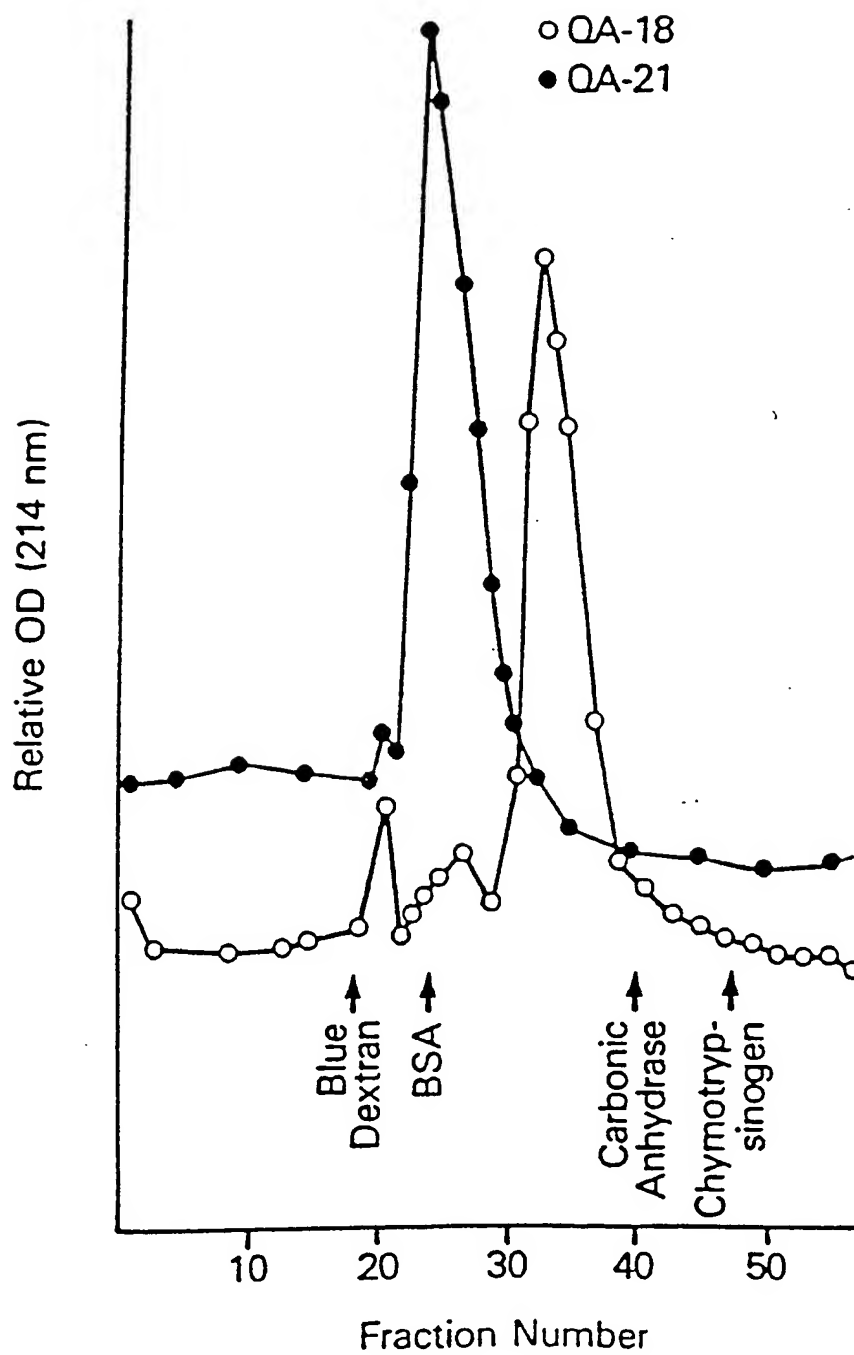


Figure 10

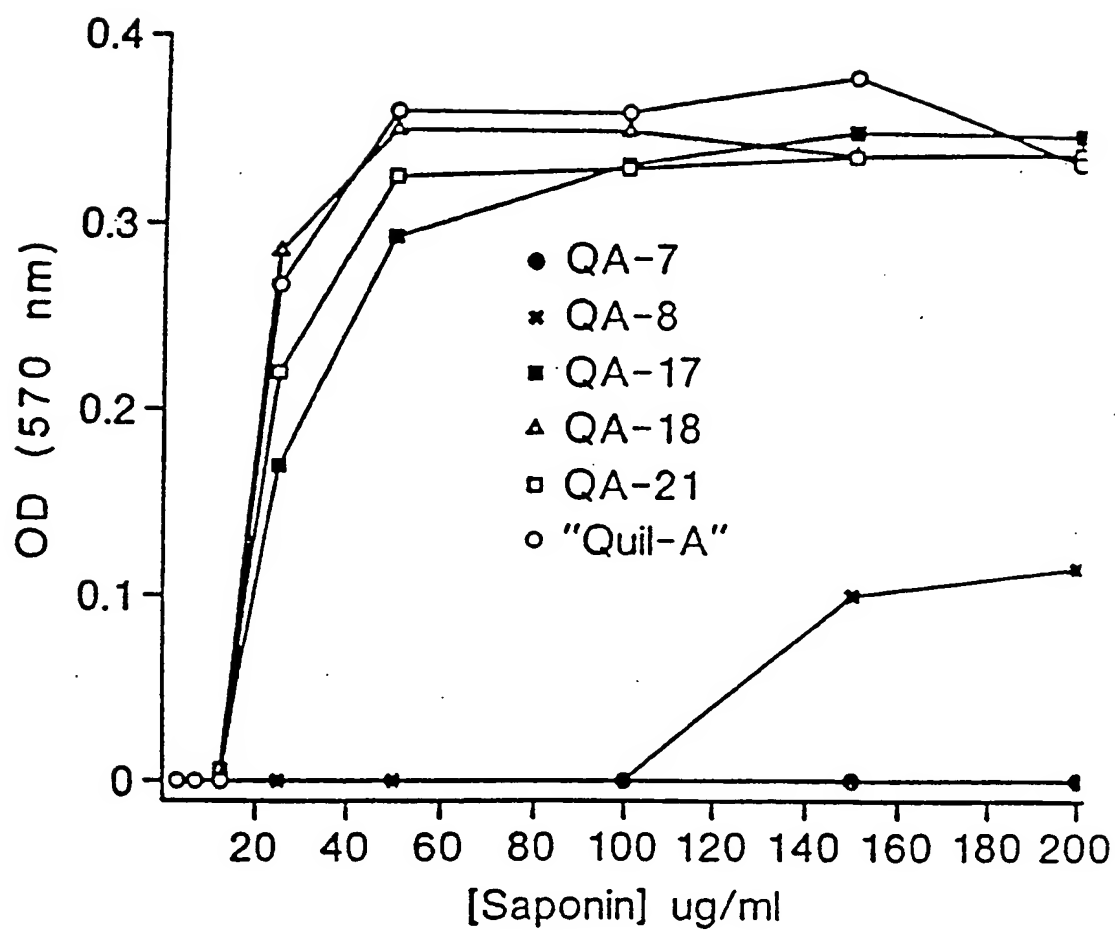
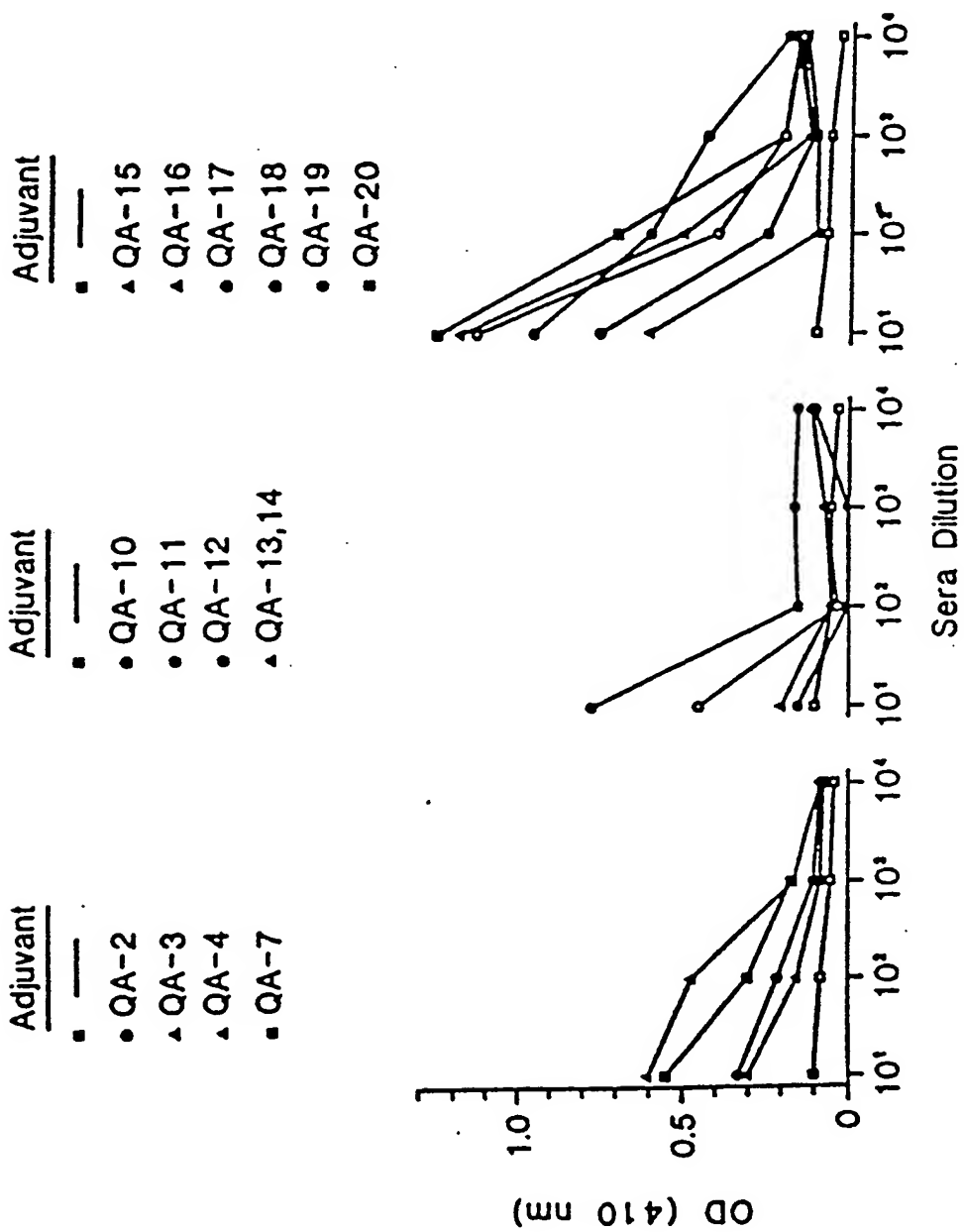


Figure 11



## Figure 12

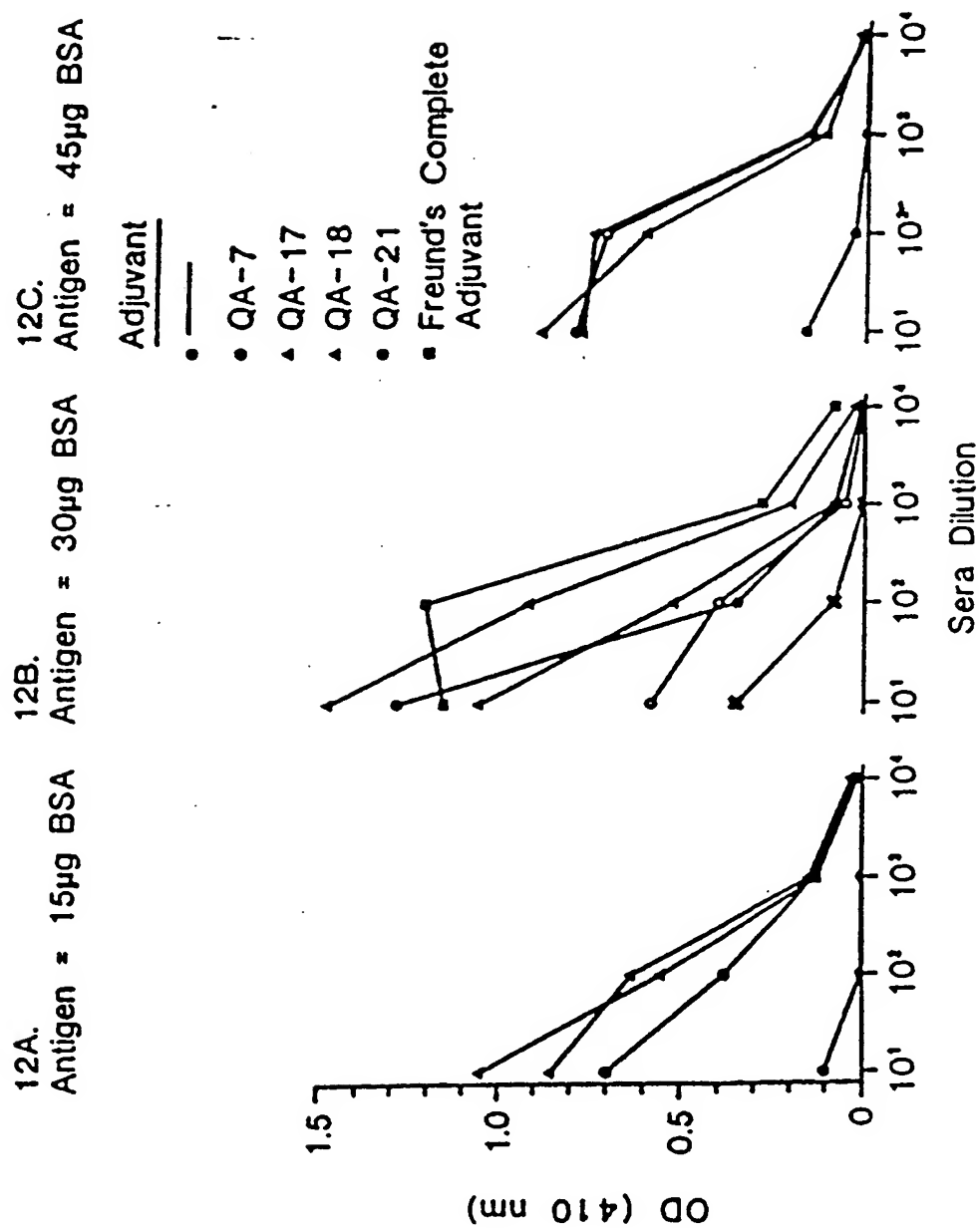


Figure 13

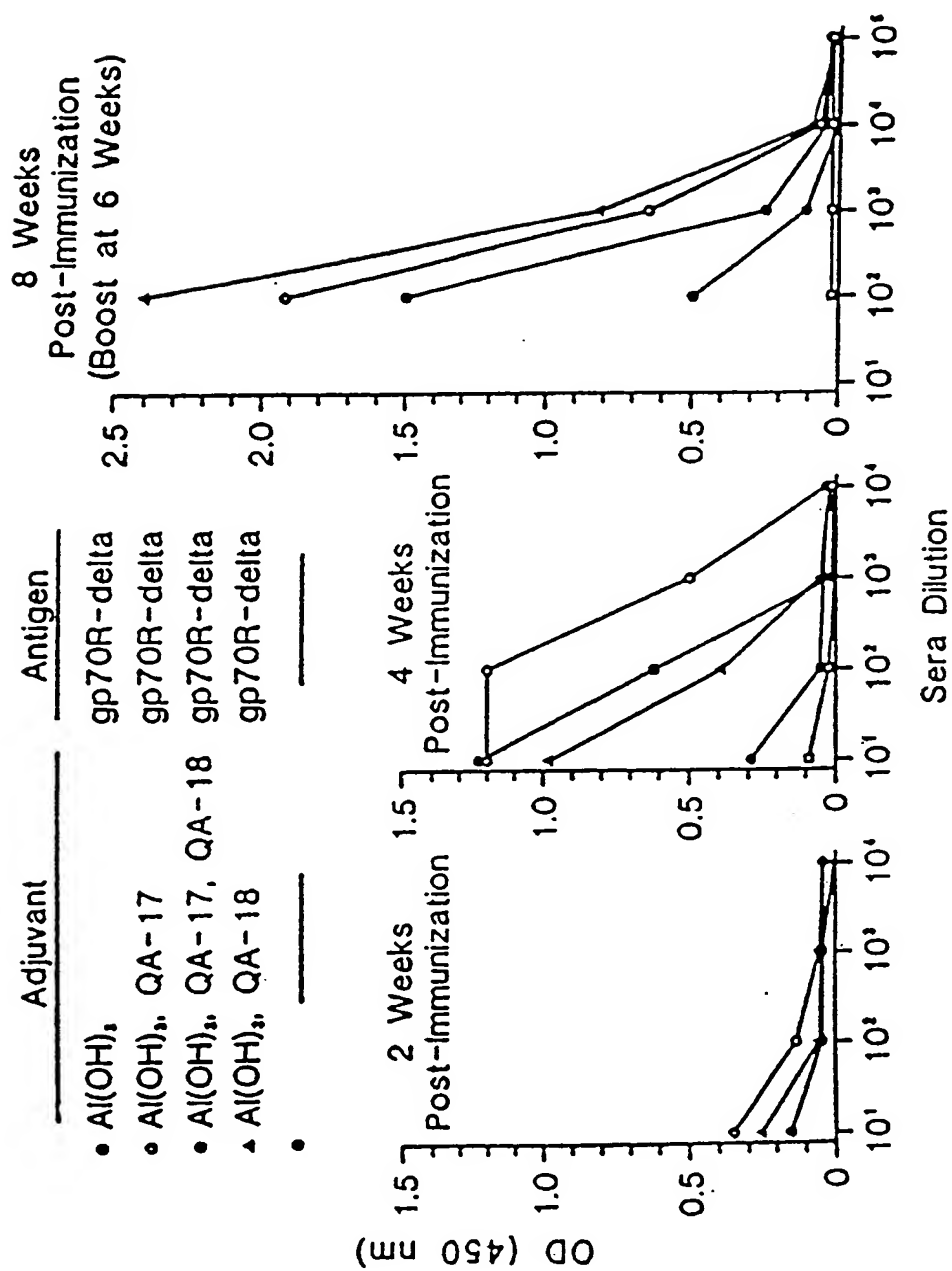


Figure 14

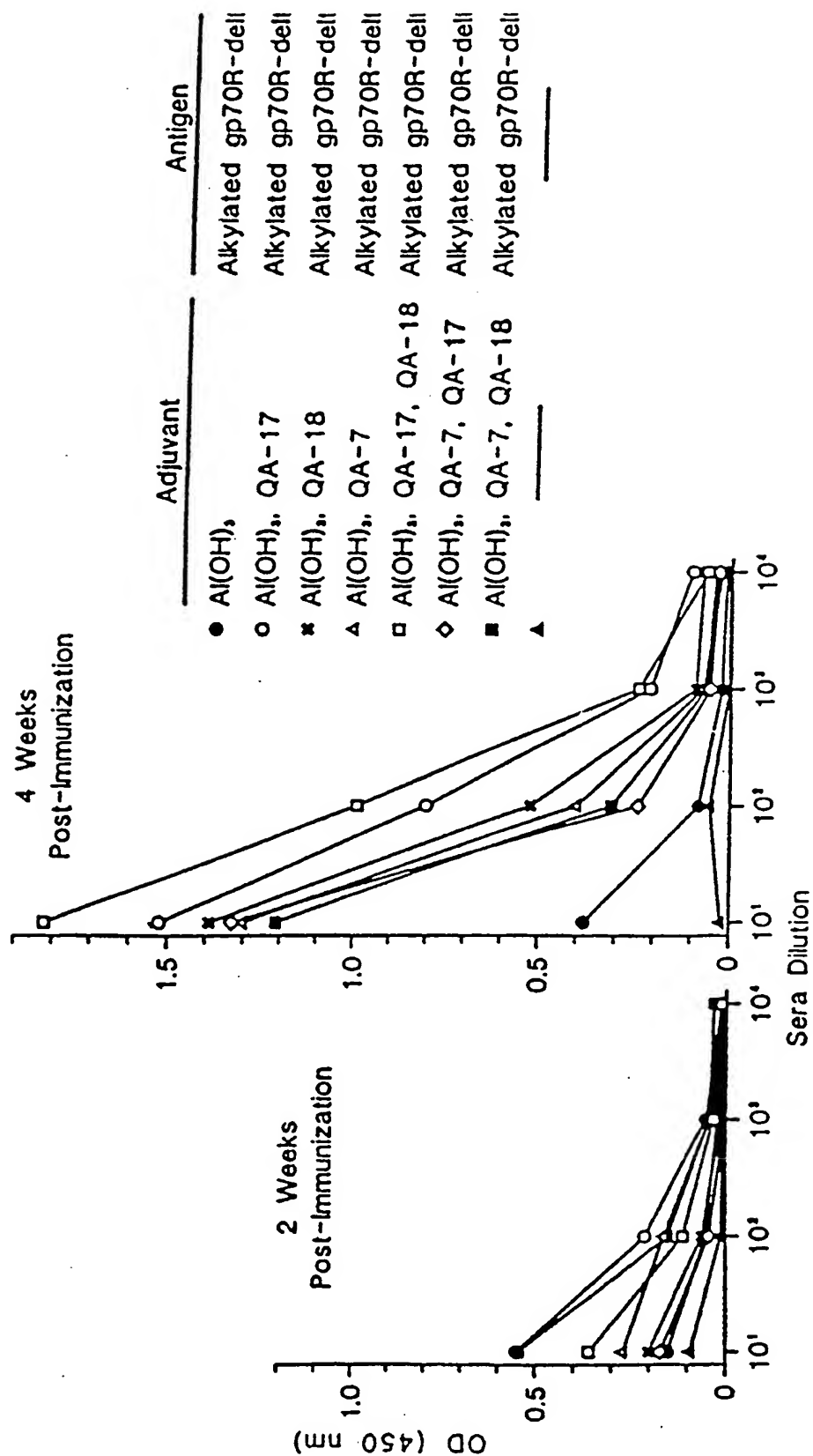
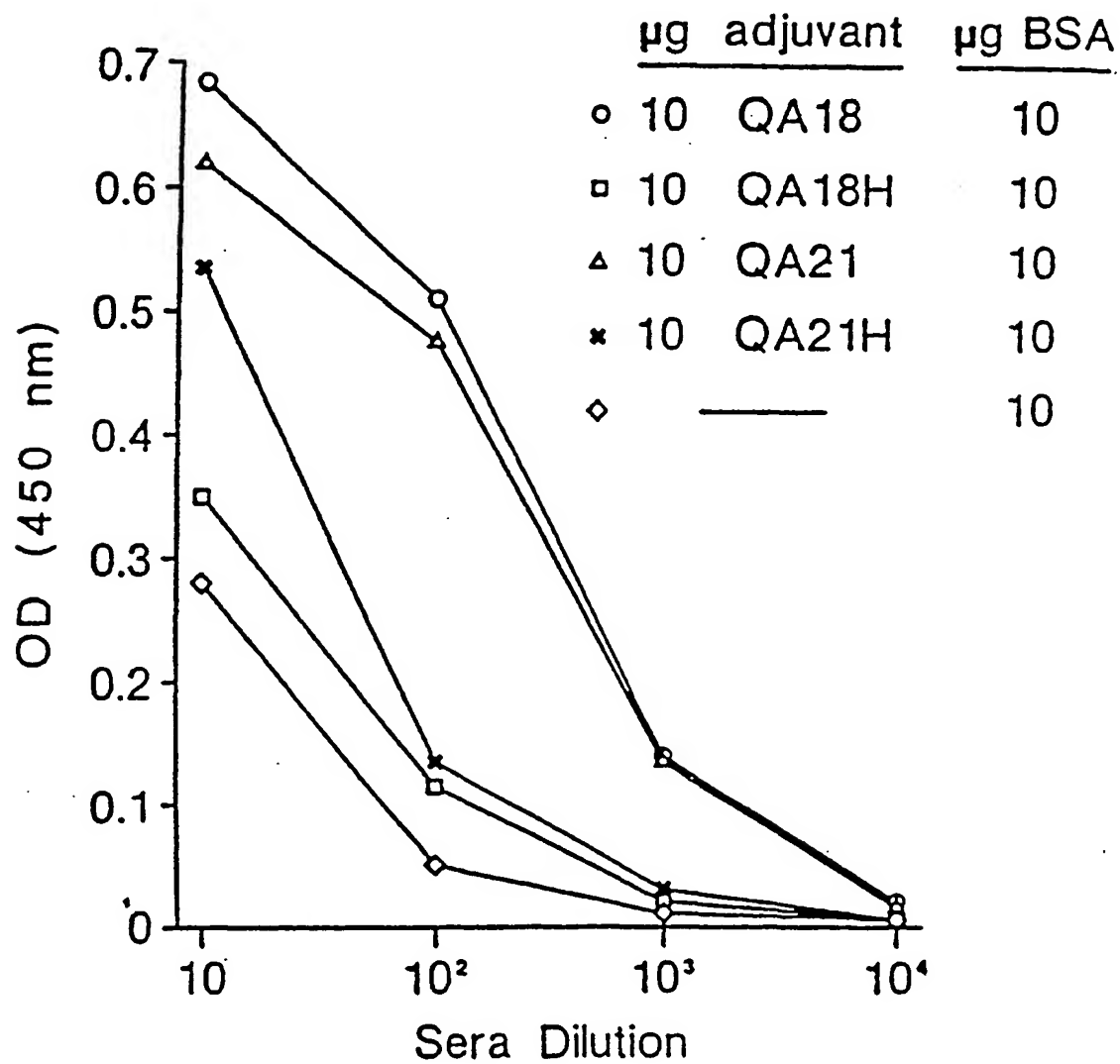


Figure 15



## SAPONIN ADJUVANT

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 07/200,754, filed 05/31/88 which is a continuation-in-part of U.S. patent application Ser. No. 055,229 filed May 29, 1987 and having the title "Saponin Adjuvant" both now abandoned.

This application is also related to U.S. patent application Ser. No. 55,298, which is a continuation-in-part of U.S. patent application Ser. No. 868,585, entitled "Method of Preparation and Use For Feline Leukemia Virus Antigens," in the names of Beltz et al.

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to the field of immune adjuvants, the process for production thereof, and the use thereof as immune adjuvants and vaccines.

## 2. Brief Description of the Background Art

Quillaja saponins are a mixture of triterpene glycosides extracted from the bark of the tree *Quillaja saponaria*. Crude saponins have been extensively employed as adjuvants in vaccines against foot and mouth disease, and in amplifying the protective immunity conferred by experimental vaccines against protozoal parasites such as *Trypanosoma cruzi* plasmodium and also the humoral response to sheep red blood cells (SRBC). (Bomford, *Int. Arch. Allerg. appl. Immun.*, 67:127 (1982)).

Saponins are natural products which have been characterized by a number of common properties. The ability to produce foam in aqueous solution gave the name to the group. Further characteristics are the hemolytic activity, the toxicity for fish, the complexing with cholesterol, and in some cases antibiotic activity. Kofler, *Die Saponine* (Springer Verlag), Berlin, 1927; Tschesche et al., *Chemie und Biologie der Saponine. Fortscher. Chem. Oro. Naturst.* XXX:461 (1972).

The common properties of saponins are not reflected in a common chemical composition. Although all saponins are glycosides, the aglycone may belong to the steroids, the triterpenoids, or the steroidalcaloids. The number of sugar and sugar chains attached to the glycosidic bonds may vary greatly. Saponins have been produced commercially and have many uses. The commercially available Quillaja saponins are crude mixtures which, because of their variability, are not desirable for use in veterinary practice or in pharmaceutical compositions for man. Because of the variability and heterogeneity, each batch must be tested in animal experiments to determine adjuvant activity and toxicity. The impurities in the commercially available products may produce adverse reactions. In addition, the content of the active substance in a given batch of saponin may vary, thereby decreasing the reproducibility from batch to batch.

An early attempt to purify Quillaja saponin adjuvants was made by Dalsgaard, *Archiv fuer die gesamte Virusforschung* 44:243 (1974). Dalsgaard partially purified an aqueous extract of the saponin adjuvant material from *Quillaja saponaria* Molina. Dalsgaard's preparation, commercially available from Superfos under the name "Quil-A," has been isolated from the bark of the South American tree, *Quillaja saponaria* Molina, and is characterized chemically as a carbohydrate moiety in glycosidic linkage to the triterpenoid quillaic acid. However,

while the saponin Quil A of Dalsgaard presents a definite improvement over the previously available commercial saponins, it also shows considerable heterogeneity.

Higuchi et al., *Phytochemistry* 26:229 (January, 1987) treated a crude Quillaja saponin mixture with alkaline hydrolysis in 6%  $\text{NH}_4\text{HCO}_3$  in 50% methanol and generated two major desacylsaponins, termed DS-1 and DS-2. DS-1 was shown to contain glucuronic acid, galactose, xylose, fucose, rhamnose, apiose, and Quilajic acid, whereas DS-2 contained these same components plus an additional glucose. Byproducts of this deacylation produced multiple components including 3,5-dihydroxy-6-methyloctanoic acid, 3,5-dihydroxy-6-methyloctanic acid, 5- $\alpha$ -L-arabinofuranoside and 5-O- $\alpha$ -L-rhamnopyranosyl-(1->2)- $\alpha$ -L-arabinofuranoside (Higuchi et al., *Phytochemistry* 26:2357 (August, 1987)).

## BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 shows the refractive index profile of dialyzed, methanol-solubilized Quillaja bark extract on reverse phase-HPLC.

FIG. 2 shows that the refractive index peaks of the above sample correspond to carbohydrate peaks.

FIG. 3 shows the comparison of Superfos "Quil-A" and dialyzed methanol soluble bark extract by HPLC.

FIG. 4 shows the purification of QA-7, QA-17, QA-18, QA-19, and QA-21 from "Quil-A," a crude saponin mixture, by silica chromatography (4A) and subsequent reverse phase chromatography (4B, 4C, 4D).

FIG. 5 demonstrates the purity of QA-7, QA-17, QA-18, and QA-21 by reverse phase (5A) and normal phase (5B) thin layer chromatography.

FIG. 6A shows the UV spectrum of QA-7. FIG. 6B shows the UV spectrum of QA-17. FIG. 6C shows the UV spectrum of QA-18. FIG. 6D shows the UV spectrum of QA-21.

FIG. 7A shows  $^1\text{H}$  Nuclear Magnetic Resonance ("NMR") of QA-7. FIG. 7B shows  $^1\text{H}$  NMR of QA-18. FIG. 7C shows  $^1\text{H}$  NMR of QA-21.

FIG. 8A shows the mass spectroscopy-fast atom bombardment ("MS-FAB") spectrum of QA-7. FIG. 8B shows the MS-FAB spectrum of QA-17. FIG. 8C shows the MS-FAB spectrum of QA-21.

FIG. 9 shows the elution profile of pure QA-18 micelles and pure QA-21 micelles by gel filtration on Bio-Gel P-200 in PBS equilibrated with the critical micellar concentration of the same saponin and a comparison with the elution position of standard proteins.

FIG. 10 shows the hemolysis of sheep red blood cells by QA-7, QA-8, QA-17, QA-18, QA-21, and Superfos "Quil-A."

FIG. 11 shows the typical endpoint titers for immunization with BSA antigen in the presence of HPLC-purified fractions of bark extract. Absorbance due to antigen-specific antibody binding was plotted as a function of the logarithm of the sera dilution.

FIG. 12 demonstrates the comparison of the adjuvant effects of QA-7, QA-17, QA-18 and QA-21 at various antigen concentrations and with Freund's complete adjuvant on immunization with the antigen BSA.

FIG. 13 shows the adjuvant effects of HPLC-purified adjuvants used in conjunction with  $\text{Al}(\text{OH})_3$ , another adjuvant, on the immunization with the antigen gp70R-delta.

FIG. 14 summarizes the effects of HPLC-purified Quillaja saponins alone and in combination with each

other and with another adjuvant on the immunization with the antigen alkylated gp70R-delta.

FIG. 15 shows a comparison of the adjuvant effects of QA-18, QA-18H, QA-21, and QA-21H on immunization with the antigen BSA.

### SUMMARY OF THE INVENTION

A need exists for a substantially pure saponin that can be used as an adjuvant in relatively low quantities with low toxicity and side effects. Accordingly, the present invention provides substantially pure saponin adjuvants, the method for the purification thereof and a method for the use of the substantially pure saponins as immune adjuvants. The invention further includes immune response-provoking compositions comprising the saponin adjuvants in combination with an antigen component.

Adjuvant saponins have been identified and purified from an aqueous extract of the bark of the South American tree, *Quillaja saponaria* Molina. At least 22 peaks with saponin activity were separable. The predominant purified *Quillaja* saponins have been identified as QA-7, QA-17, QA-18, and QA-21. These saponins have been purified by high pressure liquid chromatography (HPLC) and low pressure silica chromatography. These four saponins have adjuvant effect in mice. QA-7, QA-17, QA-18, and QA-21, purified from Superfos "Quil-A," a crude *Quillaja* saponin preparation, are less toxic in mice than "Quil-A"; QA-17 and QA-18 are less toxic in cats than "Quil-A" (QA-7, QA-21 were not tested). In addition, a toxic component of Superfos "Quil-A" has been identified as QA-19; this component is toxic in mice at lower doses than "Quil-A" or QA-7, QA-17, QA-18, and QA-21. The increased toxicity of QA-19 compared to QA-7, QA-17, QA-18, and QA-21 is unexpected in that this component is a saponin, has a similar carbohydrate composition, exhibits adjuvant activity in mice at doses lower than the toxic dose, and exhibits similar chromatographic behavior. All of the above saponins may be isolated from aqueous extracts of *Quillaja saponaria* Molina bark. The substantially pure saponins of the present invention are useful as immune adjuvants and enhance immune responses in individuals at a much lower concentration than the previously available heterogeneous saponin preparations without the toxic effects associated with crude saponin preparations.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The saponins of the present invention may be obtained from the tree *Quillaja saponaria* Molina.

The term "saponin" as used herein includes glycosidic triterpenoid compounds which produce foam in aqueous solution, have hemolytic activity in most cases, and possess immune adjuvant activity. The invention encompasses the saponin per se, as well as natural and pharmaceutically acceptable salts and pharmaceutically acceptable derivatives. The term "saponin" also encompasses biologically active fragments thereof.

The invention also concerns compositions, such as immunologic compositions, comprising one or more substantially pure saponin fractions, and methods of using these compositions as immune adjuvants.

The term "immune adjuvant," as used herein, refers to compounds which, when administered to an individual or tested in vitro, increase the immune response to an antigen in the individual or test system to which said antigen is administered. Some antigens are weakly im-

munogenic when administered alone or are toxic to the individual at concentrations which evoke immune responses in said individual. An immune adjuvant may enhance the immune response of the individual to the antigen by making the antigen more strongly immunogenic. The adjuvant effect may also lower the dose of said antigen necessary to achieve an immune response in said individual.

The adjuvant activity of the saponins may be determined by any of a number of methods known to those of ordinary skill in the art. The increase in titer of antibody against specific antigen upon administration of an adjuvant may be used as a criteria for adjuvant activity (Dalsgaard, K. (1978) *Acta Veterinaria Scandinavica* 69, 1-40, Scott, M. T., Gross-Samson, M., and Bomford, R. (1985) *Int. Archs. Allergy Appl. Immun.* 77, 409-412). Briefly, one such test involves injecting CD-1 mice intradermally with an antigen (for instance, i.e., bovine serum albumin, BSA) mixed with varying amounts of the potential adjuvant. Sera was harvested from the mice two weeks later and tested by ELISA for anti-BSA antibody. A comparison of the adjuvant effects of the dialyzed, methanol-soluble bark extract and "Quil A" showed that antibody titers were two orders of magnitude greater when the antigen BSA was administered in the presence of the saponin preparations than when BSA was administered in PBS alone. The bark extract possessed good adjuvant activity when administered at an adjuvant dose of 12 µg carbohydrate (assayed by anthrone) or more. The adjuvant response to "Quil-A" was lower than for the bark extract but was evident at doses ranging from 9-23 µg carbohydrate. Carbohydrate weight (determined by assay with anthrone using glucose as a standard) is approximately 30% of the dry weight of these crude adjuvant extracts.

The term "substantially pure" means substantially free from compounds normally associated with the saponin in its natural state and exhibiting constant and reproducible chromatographic response, elution profiles, and biologic activity. The term "substantially pure" is not meant to exclude artificial or synthetic mixtures of the saponin with other compounds.

Preferably, the substantially pure saponin is purified to one or more of the following standards: 1) appearing as only one major carbohydrate staining band on silica gel TLC (EM Science HPTLC Si60) in a solvent system of 40 mM acetic acid in chloroform/methanol/water (60/45/10, v/v/v), 2) appearing as only one major carbohydrate staining band on reverse phase TLC (EM Science Silica Gel RP-8) in a solvent system of methanol/water (70/30, v/v), 3) appearing as only one major peak upon reverse-phase HPLC on Vydac C4 (5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L) in 40 mM acetic acid in methanol/water (58/42, v/v).

In the preferred embodiment, the saponin adjuvants of the present invention are purified from *Quillaja saponaria* Molina bark. Aqueous extracts of the *Quillaja saponaria* Molina bark were dialyzed against water. The dialyzed extract was lyophilized to dryness, extracted with methanol and the methanol-soluble extract was further fractionated on silica gel chromatography and by reverse phase high pressure liquid chromatography (RP-HPLC). The individual saponins were separated by reverse phase HPLC as described in Example 1. At least 22 peaks (denominated QA-1 to QA-22) were separable. Each peak corresponded to a carbohydrate peak as demonstrated in FIG. 2 and exhibited only a single band on reverse phase thin layer chromatography. The

individual components were identified by retention time on a Vydac C<sub>4</sub> HPLC column as follows:

Peak	Retention Time (minutes)
QA-1	solvent front
QA-2	4.6
QA-3	5.6
QA-4	6.4
QA-5	7.2
QA-6	9.2
QA-7	9.6
QA-8	10.6
QA-9	13.0
QA-10	17.2
QA-11	19.0
QA-12	21.2
QA-13	22.6
QA-14	24.0
QA-15	25.6
QA-16	28.6
QA-17	35.2
QA-18	38.2
QA-19	43.6
QA-20	47.6
QA-21	51.6
QA-22	61.0

Immune adjuvant activity was tested by measuring the ability of the purified saponins to enhance the immune response in mice to exogenously administered antigens. The purified saponins of the present invention demonstrated adjuvant effects at lower doses than the crude extracts. Particularly, the predominant saponins in bark extract (QA-7, QA-17, QA-18, and QA-21) demonstrated adjuvant activity at doses of 4.5 µg carbohydrate or less (assayed by anthrone). The purified saponins were further characterized by carbohydrate content, reverse phase and normal phase TLC, UV, infra red, NMR spectra, and fast atom bombardment—mass spectroscopy.

The approximate extinction coefficient determined for 1% (w/v) solutions in methanol at 205 nm of several of the more preferred purified saponins are as follows:

	1% E <sub>205</sub> (nm)
QA-7	34
QA-17	27
QA-18	27
QA-21	28

Carbohydrate content was used to quantitate the saponins in some instances. The carbohydrate assay was the anthrone method of Scott and Melvin (*Anal. Chem.* 25:1656 (1953)) using glucose as a standard as described in Example 1. This assay was used to determine a ratio of extent of anthrone reaction (expressed in glucose equivalents) per mg of purified saponin (dry weight) so that dry weight of a particular preparation could be estimated by use of anthrone assay. It must be noted that differences in reactivity with anthrone for different saponins may be due to carbohydrate composition rather than quantity as different monosaccharides react variably in this assay.

The substantially pure QA-7 saponin is characterized as having immune adjuvant activity, containing about 35% carbohydrate (as assayed by anthrone) per dry weight, having a uv absorption maxima of 205–210 nm, a retention time of approximately 9–10 minutes on RP-HPLC on a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow

rate of 1 ml/min, eluting with 52–53% methanol from a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 10 mm ID×25 cm L in a solvent of 40 mM acetic acid with gradient elution from 50 to 80% methanol, having a critical micellar concentration of approximately 0.06% in water and 0.07% in phosphate buffered saline, causing no detectable hemolysis of sheep red blood cells at concentrations of 200 µg/ml or less, and containing the monosaccharide residues terminal rhamnose, terminal xylose, terminal glucose, terminal galactose, 3-xylose, 3,4-rhamnose, 2,3-fucose, and 2,3-glucuronic acid, and apiose (linkage not determined).

The substantially pure QA-17 saponin is characterized as having adjuvant activity, containing about 29% carbohydrate (as assayed by anthrone) per dry weight, having a UV absorption maxima of 205–210 nm, a retention time of approximately 35 minutes on RP-HPLC on a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol-water (58/42; v/v) at a flow rate of 1 ml/min, eluting with 63–64% methanol from a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 10 mm ID×25 cm L in a solvent of 40 mM acetic acid with gradient elution from 50 to 80% methanol, having a critical micellar concentration of 0.06% (w/v) in water and 0.03% (w/v) in phosphate buffered saline, causing hemolysis of sheep red blood cells at 25 µg/ml or greater, and containing the monosaccharide residues terminal rhamnose, terminal xylose, 2-fucose, 3-xylose, 3,4-rhamnose, 2,3-glucuronic acid, terminal glucose, 2-arabinose, terminal galactose and apiose (linkage not determined).

The substantially pure QA-18 saponin is characterized as having immune adjuvant activity, containing about 25–26% carbohydrate (as assayed by anthrone) per dry weight, having a UV absorption maxima of 205–210 nm, a retention time of approximately 38 minutes on RP-HPLC on a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/min, eluting with 64–65% methanol from a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 10 mm ID×25 cm L in a solvent of 40 mM acetic acid with gradient elution from 50 to 80% methanol, having a critical micellar concentration of 0.04% (w/v) in water and 0.02% (w/v) in phosphate buffered saline, causing hemolysis of sheep red blood cells at concentrations of 25 µg/ml or greater, and containing the monosaccharides terminal rhamnose, terminal arabinose, terminal apiose, terminal xylose, terminal glucose, terminal galactose, 2-fucose, 3-xylose, 3,4-rhamnose, and 2,3-glucuronic acid.

The substantially pure QA-21 saponin is characterized as having immune adjuvant activity, containing about 22% carbohydrate (as assayed by anthrone) per dry weight, having a UV absorption maxima of 205–210 nm, a retention time of approximately 51 minutes on RP-HPLC on a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/min, eluting with 69 to 70% methanol from a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 10 mm ID×25 cm L in a solvent of 40 mM acetic acid with gradient elution from 50 to 80% methanol, with a critical micellar concentration of about 0.03% (w/v) in water and 0.02% (w/v) in phosphate buffered saline, causing hemolysis of sheep red blood

cells at concentrations of 25  $\mu\text{g}/\text{ml}$  or greater, and containing the monosaccharides terminal rhamnose, terminal arabinose, terminal apiose, terminal xylose, 4-rhamnose, terminal glucose, terminal galactose, 2-fucose, 3-xylose, 3,4-rhamnose, and 2,3-glucuronic acid.

The term "individual" means any animal which can elicit an immune response, including humans.

The purified saponins exhibit adjuvant effects when administered over a wide range of dosages and a wide range of ratios to the antigen being administered. In one embodiment, the saponin is administered in a ratio of adjuvant to antigen (w/w) of 3.0 or less, preferably 1.0 or less.

The purified saponins may be administered either individually or admixed with other substantially pure adjuvants to achieve the enhancement of the immune response to an antigen. Among the adjuvant mixtures effective in the present invention are fractions QA-7 and QA-17, QA-7 and QA-18, QA-17 and QA-7, QA-17, and QA-18 administered together. Purified saponins may also be administered together with non-saponin adjuvants. Such non-saponin adjuvants useful with the present invention are oil adjuvants (for example, Freund's Complete and Incomplete), liposomes, mineral salts (for example,  $\text{AlK}(\text{SO}_4)_2$ ,  $\text{AlNa}(\text{SO}_4)_2$ ,  $\text{AlNH}_4(\text{SO}_4)$ , silica, alum,  $\text{Al}(\text{OH})_3$ ,  $\text{Ca}_3(\text{PO}_4)_2$ , kaolin, and carbon), polynucleotides (for example, poly IC and poly AU acids), and certain natural substances (for example, wax D from *Mycobacterium tuberculosis*, as well as substances found in *Corynebacterium parvum*, *Bordetella pertussis*, and members of the genus *Brucella*).

The purified saponins of the present invention may be utilized to enhance the immune response to any antigen. Typical antigens suitable for the immune-response provoking compositions of the present invention include antigens derived from any of the following: viruses, such as influenza, rabies, measles, hepatitis B, hoof and mouth disease, or HTLV-III; bacteria, such as anthrax, diphtheria or tuberculosis; or protozoans, such as *Babesiosis bovis* or *Plasmodium*.

A particular example is the use of the purified saponins of the present invention to enhance the immune response to gp70 recombinant protein. One gp70 recombinant protein is an antigen which contains the polypeptide portion of FeLV gp70 envelope protein. This recombinant antigen is termed "gp70R," "rec-gp70" or "Rgp70." Another antigen preparation which contains the polypeptide portion of FeLV gp70 together with the 40 amino-terminal amino acids (termed "Rgp70delta") or with the entire amino acid sequence (termed "Rgp90") of the p15e envelope protein of FeLV subgroup A is produced using recombinant DNA techniques. These recombinant gp70-containing polypeptides, gp70R, gp70R-delta, and gp90R, are hereinafter referred to collectively as gp70-containing protein. The term gp70-containing protein is intended to include polypeptides having the same amino acid sequence of the naturally occurring gp70-containing protein, and analogs thereof. The term "analogs" is intended to include proteins or polypeptides which differ from gp70, gp70-delta, or gp90 by addition, deletion or substitution of one or more amino acids providing that said polypeptide demonstrate substantially the biological activity of gp70 protein.

Administration of the compounds useful in the method of present invention may be by parenteral, intravenous, intramuscular, subcutaneous, intranasal, or any other suitable means. The dosage administered may

be dependent upon the age, weight, kind of concurrent treatment, if any, and nature of the antigen administered. The effective compound useful in the method of the present invention may be employed in such forms as capsules, liquid solutions, suspensions or elixirs for oral administration, or sterile liquid forms such as solutions or suspensions. Any inert carrier is preferably used, such as saline, or phosphate-buffered saline, or any such carrier in which the compounds used in the method of the present invention have suitable solubility properties for use in the method of the present invention.

Having now generally described the invention, the same may be further understood by reference to the following examples, which are not intended to be limiting unless so expressly stated.

#### EXAMPLE 1

##### Preliminary Preparation of *Quillaja Saponaria Molina* Bark Extract

*Quillaja saponaria Molina* bark was stirred with an excess of water (10% w/v) to extract the saponins. The aqueous extract was then filtered and stored in 0.1%  $\text{NaN}_3$ . 150 ml of this extract was centrifuged at  $20,000 \times g$  for 30 minutes to remove residual bark fragments. The supernatant, which was light brown, was lyophilized and redissolved in 16 ml of water and the pH was adjusted to less than 4 with the addition of 160  $\mu\text{l}$  of 1N acetic acid. This solution was placed in dialysis tubing having a 12,000 MW cut off and dialyzed against 1 liter of water. The water was changed after 8 hours of dialysis, and the dialysis was allowed to proceed overnight. Samples of the dialysate were removed after the first and second dialysis cycles. The dialyzed extract was lyophilized and extracted with 40 ml methanol at 60° C. for 15 minutes followed by centrifugation at  $1,000 \times g$  for 10 minutes to sediment the undissolved material. This material was subjected to two additional extractions with methanol. The methanol extracts were pooled, evaporated on a rotoevaporator to dryness, redissolved in 5.5 ml methanol, and filtered through a 0.2  $\mu$  nylon 66 mesh to remove residual undissolved material. Fractions were analyzed by reverse phase thin-layer chromatography (RP-TLC) on C8 plates (E.M. Science RP-TLC, C8) in a solvent system of 70% methanol/30% water or by normal phase thin layer chromatography on silica gel 60 TLC plates in a solvent system of n-butanol, ethanol, water, and ammonia (30/60/29/21, v/v/v/v). The carbohydrate bands were visualized with Bial's reagent which detected all major bands detectable by sulfuric acid charring with an increased sensitivity over the sulfuric acid charring method. The Bial's reagent carbohydrate stain was routinely used as a detection reagent on TLC plates. All major bands were glycosylated.

Dialysis removed a major carbohydrate-containing band ( $R_F=0.82$  on EM Science RP TLC, C8 in methanol/water (70/30, v/v)), as well as some minor components. In addition, dialysis removed components with strong absorption maxima at 280 and 310 nm. Approximately 80% of the carbohydrate (assayed by anthrone) was removed by dialysis, but about 95% of the hemolytic activity was retained during dialysis.

Most saponin adjuvants are known to have detergent properties, such as hemolysis of red blood cells, so the retention of hemolytic activity is a rough indication of the retention of adjuvant saponins. Several bands were retained by dialysis, indicating their detergent nature.

Methanol solubilized all TLC bands present in the dialyzed extract except one TLC band ( $R_F=0$  on both reverse-phase and silica TLC plates). The methanol-insoluble material was reddish-brown. The material which was methanol-soluble appeared white after lyophilization.

Carbohydrate concentration was determined by the method of Scott and Melvin (Scott, T. A., and Melvin, E. H. *Anal. Chem.* 25, 1656 (1953)). Briefly, an aqueous sample to be tested or glucose as a standard carbohydrate solution (450  $\mu$ l) was mixed with 900  $\mu$ l of 0.2% anthrone (w/v) in sulfuric acid and incubated for 16 min at 90°-100° C. The absorbance was read at 625 nm. Glucose was used as a standard.

The hemolytic activity of the samples was determined as follows: Briefly, samples were diluted in a round bottom microtiter plate with 1:2 dilutions in phosphate buffered saline in successive rows (100  $\mu$ l/well). 10  $\mu$ l normal rabbit blood in Alsevers solution (Hazelton) was added to each well and mixed. Plates were incubated for one hour at room temperature followed by centrifugation of the plates in a Sorvall RT6000 to sediment unhemolyzed cells. Absence of hemolysis was determined by the presence of a pellet of unhemolyzed cells in the bottom of the well.

#### EXAMPLE 2

Comparison of Dialyzed, Methanol-Soluble Bark Extract and Superfos "Quil-A" by TLC and HPLC

Superfos "Quil-A" and dialyzed, methanol-soluble components of bark extract prepared as in Example 1 were compared by reverse phase TLC as described in Example 1. All bands present in the bark extract after dialysis and solubilization with methanol were present in "Quil-A." In addition, "Quil-A" contained a band with  $r_f=0$  on reverse-phase TLC plates; this component was removed by methanol-solubilization as described above. The similarity in composition of dialyzed, methanol-soluble bark extract and "Quil-A" was confirmed by HPLC. The individual components of bark extract were separable by reverse-phase HPLC on Vydac C4 (5  $\mu$ m particle size, 330 Å pore, 4.6 mm ID  $\times$  25 cm L) in 40 mM acetic acid in methanol/water (58/42, v/v). The refractive index of the individual fractions was determined. FIG. 1 represents the refractive index profile of the peaks (labeled QA-1 to QA-22 in order of increasing retention times) from the RP-HPLC. The relative proportion of each peak in bark extract and Superfos "Quil-A" is shown on Table 1, below.

TABLE 1

Relative proportion of HPLC fractions of crude saponin extract and Superfos "Quil-A" (refractive index) % of Total (peaks 2-21)		
HPLC Fraction	Dialyzed, methanol-soluble bark extract	Superfos "Quil-A"
QA-2	3.1	1.2
QA-3	4.8	2.4
QA-4,5	10.1	7.1
QA-6,7	17.5	12.7
QA-8	6.8	10.5
QA-9	1.0	2.1
QA-10	2.7	1.3
QA-11	6.8	6.2
QA-12	3.5	5.6
QA-13,14,15	4.8	7.7
QA-16	2.8	1.4
QA-17	11.4	9.9

TABLE 1-continued

Relative proportion of HPLC fractions of crude saponin extract and Superfos "Quil-A" (refractive index) % of Total (peaks 2-21)		
HPLC Fraction	Dialyzed, methanol-soluble bark extract	Superfos "Quil-A"
QA-18	13.5	21.8
QA-19	2.2	4.5
QA-20	3.2	2.2
QA-21	5.6	3.7

The individual peaks correspond to single thin-layer chromatography bands on reverse-phase TLC plates. Another representative experiment shown on FIG. 2 demonstrates that the refractive index peaks also correspond to carbohydrate peaks, confirming that all major bark extract components are glycosides (HPLC fractions assayed for carbohydrate by the anthrone assay).

Dialyzed, methanol-soluble bark extract and "Quil-A" were compared directly in this HPLC system. The individual components were identified by retention time. All peaks present in dialyzed, methanol-soluble bark extract were also present in "Quil-A" in similar proportions with the exception of a higher proportion of component QA-8 and a lower proportion of component QA-17 in Superfos "Quil-A" compared to bark extract. FIG. 3 shows a comparison of dialyzed, methanol-soluble bark extract and Superfos "Quil-A" using a semipreparative Vydac C4 (10 mm ID  $\times$  25 cm L, 330 Å pore size, 5  $\mu$ m particle size). The sample is loaded in 50% methanol in 40 mM acetic acid and a methanol gradient in 40 mM acetic acid (shown in FIG. 3) is used to elute the samples. The absorbance was monitored at 214 nm.

Various samples of Quillaja bark were extracted and analyzed by HPLC. There was some variability in the relative proportions of the peaks, but the same peaks were always present. It is not presently known whether the variability in proportions is due to variability in the efficiency of the extraction process or in bark from different sources.

Due to the ready availability of "Quil-A" and the similar composition to bark extract, "Quil-A" was utilized to produce mg quantities of material. Adjuvant activity in mice, using BSA as antigen, was found to be associated with peaks 4, 7, 11, 12, 15, 16, 17, 18, 19, and 20 (Table 2) at doses of 3.0  $\mu$ g carbohydrate (determined by the anthrone assay). The absorbance due to antigen-specific antibody binding (two weeks post-immunization, determined by ELISA) at a sera dilution of 1:10 provides a semi-quantitative estimate of adjuvant activity (ranging from 0.07 in mice immunized in the absence of adjuvant to 1.24 in mice immunized in the presence of QA-20).

TABLE 2

Adjuvant Activity in Mice		
HPLC Fraction	Adjuvant Dose ( $\mu$ g carbohydrate)	Absorbance* (410 nm)
QA-2	3.0	.34
QA-3	3.0	.27
QA-4	3.0	.60
QA-7	3.0	.49
QA-10	3.0	.13
QA-11	3.0	.46
QA-12	3.0	.76
QA-13,14	3.0	.20
QA-15	3.0	1.17

TABLE 2-continued

HPLC Fraction	Adjuvant Activity in Mice	
	Adjuvant Dose ( $\mu$ g carbohydrate)	Absorbance* (410 nm)
QA-16	3.0	.66
QA-17	3.0	1.13
QA-18	3.0	.75
QA-19	3.0	.93
QA-20	3.0	1.24
		0.07

\*Absorbance due to antigen-specific antibody binding at sera dilution of 1:10.

Due to the predominance of peaks QA-7, QA-17, QA-18, and QA-21 in bark extract, these four components were purified on a layer scale, as described in Examples 3 and 4, below.

### EXAMPLE 3

#### Purification by Silica Chromatograph

1 gram "Quil-A" was suspended in 75 ml methanol and heated at 60° for 15 minutes and filtered. The undissolved material was extracted a second time with 50 ml methanol at 60° C. and filtered. The filtrates were evaporated to dryness on the rotoevaporator. A Lichropep Silica Si60 column (E.M. Science, 25 mm ID $\times$ 310 mm L, 40–63  $\mu$ m particle size) was pre-equilibrated in 40 mM acetic acid in chloroform/methanol/water (62/32/6, v/v/v).

The dried "Quil-A," a crude mixture of saponins, was dissolved in 5 ml of column solvent and eluted through the silica isocratically in this solvent system at a flow rate of 1 ml/min. Carbohydrate analysis, thin-layer chromatography, and HPLC were used to monitor the fractions for QA-7, QA-17, QA-18, and QA-21. Fractions 19–30 were enriched in QA-21 and were pooled for further purification of QA-21. Fractions 31–60 were enriched in QA-8 and QA-18 and were pooled for further purification of these components. Fractions 85–104 were enriched with QA-7 and QA-17 and were pooled for further purification of these components. These pools were flash evaporated prior to further purification.

### EXAMPLE 4

#### Further Purification by Reverse Phase HPLC

Silica fractions were further purified by semipreparative reverse phase HPLC on Vydac C<sub>4</sub> (10 mm ID $\times$ 25 cm L), FIG. 4. Silica fractions (10–20 mg) were dissolved in the appropriate solvent and loaded on Vydac C<sub>4</sub>. A methanol gradient was used to elute the fractions. The flow rate was 3 ml per minute. The fractions were monitored by absorbance at 214 nm. FIG. 4B shows the purification of QA-21 from silica fractions 19–30 using isocratic separation in 40 mM acetic acid in 58% methanol/42% water. Fractions eluting with a retention time between 65–72 minutes were identified as QA-21 by reverse phase TLC and pooled for further characterization. FIG. 4C shows the purification of QA-18 from silica fractions 31–60 using a methanol gradient in 40 mM acetic acid (50–56% methanol/0–10 min, 56–69% methanol/10–79 min). Fractions eluting with a retention time between 46–48 minutes were identified as QA-18 by reverse phase TLC and pooled for further characterization. FIG. 4D shows the purification of QA-7 and QA-17 from silica fractions 85–104 using the same gradient used in FIG. 4C. Fractions eluting with a retention time between 21–23 minutes were identified as

QA-17 by reverse phase TLC and pooled for further characterization. Fractions eluting with a retention time between 44–46 minutes were identified as QA-17 by reverse phase TLC and were pooled for further characterization.

### EXAMPLE 5

#### Purity and Characterization of Adjuvants Purified by Silica and Reverse Phase Chromatography

##### Purity

FIG. 5a represents a reverse-phase TLC (E.M. Science RP-TLC, C8 (Solvent=70% methanol, visualization spray=Bial's reagent)). 5  $\mu$ g each of QA-7, QA-17, QA-18, and QA-21 purified as described in Example 3 and 4, were chromatographed. The adjuvants each appeared as single bands in this TLC system.

FIG. 5b demonstrates fractions QA-7, QA-17, QA-18, QA-21 and "Quil-A" on EM Si60 HPTLC plate (solvent=40 mM acetic acid in chloroform/methanol/H<sub>2</sub>O (60/45/10, v/v/v), visualization spray=Bial's reagent). 2  $\mu$ g each of QA-7, QA-17, QA-18 and QA-21, purified as described in Examples 3 and 4, and 20  $\mu$ g of "Quil-A," a crude saponin extract, were chromatographed. The HPLC-purified material appeared predominantly as a single band.

##### Spectroscopy

The UV spectra of QA-7, QA-17, QA-18 and QA-21 in methanol are shown on FIGS. 6A–D respectively. Dalsgaard's (Dalsgaard, K., *Acta Veterinaria Scandinavica Supp.* 69:1–40 (1978)) adjuvant fraction had an absorbance peak at 280 nm; however, the HPLC-purified fractions of the present invention do not have a peak at 280 nm but have a major peak in the region between 200–220 nm with a shoulder centered at 260 nm.

Fourier Transform-Infrared Resonance ("FT-IR") spectra showed little difference between the adjuvants, suggesting that they all have the same functional groups. Although identification of the structure cannot be made from the IR, the spectral data is consistent with the presence of a carboxyl group as was suggested by Dalsgaard (Dalsgaard, K., *supra*).

<sup>1</sup>H-NMR at 250 MHz of the purified saponins in CD<sub>3</sub>OD demonstrates the complex nature of the purified saponins QA-7 (FIG. 7A), QA-18 (FIG. 7B), and QA-21 (FIG. 7C). The signals in the region between 4.1 to 5.4 ppm clearly demonstrate the presence of multiple signals from the anomeric protons of the monosaccharides, indicating a multiplicity of monosaccharide residues. However, the NMR spectra of the saponins are too complex to allow structural determination.

MS-FAB of the purified saponins QA-7, QA-17, and QA-21 (FIGS. 8A, 8B, 8C, respectively) indicated approximate pseudo-molecular ion masses of 1870, 2310, and 1980, respectively. MS-FAB was not determined on QA-18 due to difficulties in solubilizing this component. These molecular weights are consistent with those expected for a triterpene linked to eight to ten monosaccharide residues and were in the same range as monomer molecular weights determined by size exclusion HPLC of purified saponins in methanol (Zorbax PSM 60 Si column, 25 cm $\times$ 6.2 mm, 1 ml/min flow rate, molecular weight standards=18- $\beta$ -glycerhetinic acid and ginenoside Rb<sub>1</sub>) which indicated approximate molecular weights of 2600, 2400, 1800, and 2400 for QA-7, QA-17, QA-18, and QA-21, respectively. The difference between FAB-MS and size exclusion HPLC are

most likely due to variation in shape between the saponins and the molecular weight standards.

#### Carbohydrate Composition

Table 3 below shows the carbohydrate composition and linkage analysis of purified saponins QA-7, QA-17, QA-18, QA-21, and QA-19. The carbohydrate in saponins was converted to alditol acetates by heating 0.2 mg saponin in 0.3 ml 2N trifluoroacetic acid containing 0.1 mg/ml inositol at 120° C. for two hours. The acid was removed under a flow of air, and residual acid removed by the addition of isopropanol (2×0.25 ml), followed by blowing to dryness with air. The dry residue obtained was dissolved in 1M ammonium hydroxide (0.25 ml) containing 10 mg/ml sodium borodeuteride and kept for one hour at room temperature. Glacial acetic acid (0.1 ml) was added, and the solution was blown to dryness. Residual borate was removed by co-distilling with 10% acetic acid in methanol (3×0.25 ml) and finally with methanol (2×0.25 ml). The dry residue in acetic anhydride (0.1 ml) and pyridine (0.1 ml) was heated for 20 minutes at 120° C. Toluene (9.02 ml) was added to the cooled solution, and the solvents removed under a flow of air. This procedure of adding toluene and removing pyridine and acetic anhydride was repeated twice. The residue obtained was taken up in dichloromethane (0.5 ml) and extracted with water (0.5 ml). The organic phase was transferred to a clean tube and dried. Prior to analysis by GLC (gas-liquid chromatography), the residue was dissolved in acetone (0.1 ml). Alditol acetates were analyzed on an SP2330 capillary GLC column (30 m×0.25 mm) at 235° C. with flame ionization detection. The carbohydrate in saponins was converted to trimethylsilylated methylglycosides by heating 0.1 mg of sample in methanolic HCl (0.3 ml) containing 50 µg/ml inositol for 16 hours at 80° C. The sample was blown to dryness, and residual acid removed by the addition of t-butyl alcohol (2×0.25 ml) followed by drying with a flow of air. The dry residue was dissolved in a solution (0.2 ml) containing pyridine, hexamethyldisilazane, and trimethylchlorosilane (5:1:0.5 v/v, "Tri-Sil") and heated for 20 minutes at 80° C. The silylating reagent was evaporated at room temperature, and the residue dissolved in hexane (1 ml). After removal of the

a 2°/min increase to 200° C. and then a 10°/min increase to 260° C. with flame ionization detection.

Glycoside linkage analysis was carried out by the following method: To the sample (≈1 mg) dissolved in dry dimethylsulfoxide (0.2 ml), 0.2 ml of potassium dimethylsulphinylium anion (2M) was added, and the mixture stirred for 12 hours under argon. The reaction mixture was cooled in ice, and methyl iodide (0.2 ml) was added drop wise. The resulting mixture was sonicated and stirred at room temperature for one hour. The methylated material was isolated using Sep-Pak C<sub>18</sub> cartridges conditioned with ethanol (20 ml), acetonitrile (8 ml), and water (10 ml). Water (1 ml) was added to the methylation reaction mixture, and the excess methyl iodide removed by passing nitrogen through the solution. The clear solution was applied to the cartridge which was washed with water (8 ml) and 20% acetonitrile (5 ml). The methylated material was eluted from the cartridge with 100% acetonitrile (4 ml) and ethanol (4 ml). The solvents were removed with a flow of air. The dried methylated material was treated with 0.3 ml of "super deuteride" solution at room temperature for one hour in order to reduce the uronic acid residues to the corresponding hexoses. After destroying the excess reagent with glacial acetic acid (0.1 ml), the reaction mixture was blown to dryness with 10% acetic acid/methanol and blown to dryness two more times. The resulting reduced methylated material in methanol was passed through a column of Dowex-50 W(H<sup>+</sup>) and the effluent obtained was dried. The reduced methylated material was converted to methylated alditols as described in section 1 above and analyzed by GLC (SP2330 fused silica column (30 m×0.25 mm), 3 min at 170° C. followed by 4°/min to 240° C.) and GLC-MS (SP2330 fused silica column (30 m×0.25 mm), 2 min at 80° C. followed by 30°/min to 170° C. followed by 4°/min to 240° C. followed by holding at 240° C. for 10 min, mass spectral analysis on Hewlett-Packard MSD).

Despite the similarity in the carbohydrate composition, subtle differences distinguish the individual saponins, in particular, the absence of arabinose in QA-7 and decreased glucose in QA-21 compared to the other saponins.

TABLE 3

	Carbohydrate Composition and Linkage Analysis of Purified Saponins														
	QA-7			QA-17			QA-18			QA-19A			QA-21		
	AA <sup>a</sup>	TMS <sup>b</sup>	Linkage	AA	TMS	Linkage	AA	TMS	Linkage	AA	TMS	Linkage	AA	TMS	Linkage
rhamnose	191.4	1.57	T <sup>c</sup>	184.8	1.9	T	132.0	0.99	T	32.7	1.69	T	131.9	1.07	T
			3,4			3,4			3,4			3,4			4
fucose	86.7	0.67	2,3	77.9	0.78	2	95.6	0.76	2	26.6	0.88	2	99.8	0.76	2
arabinose	trace	trace		65.4	0.80	2	80.1	0.64	T	31.1	0.94	T	71.0	0.65	T
xylose	98.1	0.95	T	81.8	1.08	T	117.8	1.16	T	49.9	2.07	T	114.3	1.21	T
			3			3			3			3			3
galactose	81.2	0.74	T	69.4	0.81	T	88.1	0.86	T	trace	1.11	T	88.1	0.84	T
glucose	81.2	1.0	T	85.7	1.0	T	89.2	1.00	T	trace	1.0	T	19.6	0.30	T
glucuronic acid	N.T. <sup>d</sup>	0.48	2,3	N.T.	0.52	2,3	N.T.	0.62	2,3	29.2	0.62	2,3	N.T.	0.62	2,3
apiose <sup>e</sup>	22.5	N.T.		24.5	N.T.		25.7	N.T.	T	27.7		T	20.0	N.T.	T

<sup>a</sup>Alditol acetate (µg/mg saponin)

<sup>b</sup>Trimethylsilylated methyl glycosides (relative proportions)

<sup>c</sup>T-terminal glycosyl residue, that is, attached through C-1 but with no other residues attached to it. 3,4 = a glycosyl residue attached through C-1 with other glycosyl residues glycosidically attached to it through C-3 and C-4.

<sup>d</sup>Not tested

<sup>e</sup>Poor recovery as alditol acetates

insoluble residue by filtration using glass wool plug, the filtrate was transferred to a clean tube and evaporated. The residue was dissolved in hexane (0.2 ml) prior to analysis by GLC. The trimethylsilylated methyl glycosides were analyzed on a GLC column of fused silica DB1 (25 m×0.25 mm) for 3 min at 160° C. followed by

#### Characterization of Saponins as Detergents

The critical micellar concentration of adjuvants QA-7, QA-17, QA-18, and QA-21 was determined by the method of DeVendittis et al. (DeVendittis, E., Palumbo, G., Parlato, G., and Bocchini, V. (1981) *Anal.*

*Biochem.* 115, 278-286) as follows: The emission spectrum of 1-anilinoanthracene-8-sulfonic acid (ANS) in water was determined at dry weight concentrations of adjuvant ranging from 0.01 to 0.10% (W/v) to cover the range below and above the critical micellar concentration. Above the critical micellar concentration, the fluorescence yield of ANS increases and the wavelength of maximum emission decreases due to partitioning of the fluorescent dye into the micelles. Similar critical micellar concentrations were found for QA-7, QA-17, QA-18, and QA-21 in water (0.06%, 0.06%, 0.04%, and 0.03%, respectively) with slightly lower concentrations determined in phosphate buffered saline (0.07% 0.03%, 0.02%, and 0.02%, respectively).

FIG. 9 shows the gel filtration chromatograph for micelles formed by purified QA-18 and QA-21 (on Bio-Gel P-200 (6.6 mm ID×90 cm ht)), pre-equilibrated in a concentration of purified saponin equivalent to the critical micellar concentration of that saponin in phosphate buffer saline to prevent the monomer-micelle equilibrium from reducing the apparent radius of the micelles). QA-18 and QA-21 micelles elute with a size that is similar to that of the protein bovine serum albumin.

The hemolytic activity of the adjuvants was determined by the following method: Dilutions of adjuvants QA-7, QA-8, QA-17, QA-18, QA-21, and Superfos "Quil-A" were made on a round bottom, microtiter plate (75  $\mu$ l per well). Sheep red blood cells (SRBC), washed three times with PBS, were diluted to 4% with PBS. SRBC (25  $\mu$ l) were added to each well and mixed with adjuvant. After incubation at room temperature 30 min, the plates were spun at 1000 rpm 5 min in a Sorvall RT6000, H-1000 rotor, to sediment unhemolyzed cells. 50  $\mu$ l of the supernatant from each well was transferred to the same well of a flat bottom microtiter plate and diluted to 200  $\mu$ l with H<sub>2</sub>O. Absorbance was determined at 570 nm with a Dynatech microtiter plate reader. (FIG. 9) Hemolysis increased the absorbance at 570 nm due to release of hemoglobin from the lysed cells. Significant differences in hemolysis were observed between adjuvants. QA-17, QA-18, QA-21, and Superfos "Quil-A" caused partial hemolysis at concentrations as low as 25  $\mu$ g/ml whereas partial hemolysis was observed with QA-8 at 150  $\mu$ g/ml. No hemolysis was observed with QA-7 at the concentrations tested (200  $\mu$ g/ml and less).

#### EXAMPLE 6

##### Isolation of Toxic Component QA-19

The toxic component QA-19 cochromatographs with QA-18 on silica and is enriched in silica fractions 31-60. These fractions were pooled and flash evaporated prior to further purification. FIG. 4C shows the separation of QA-19 from QA-18 by reverse phase HPLC on Vydac C<sub>4</sub> (10 mm ID×25 cm L) using a methanol gradient. Fractions eluting with a retention time between 50-52 minutes were identified as QA-19 by reverse phase TLC and analytical HPLC and pooled for further characterization. QA-19 could be further separated into two peaks by repurification in a shallower methanol gradient, with the peak with shorter retention time designated QA-19a and the peak with longer retention time designated QA-19b. Carbohydrate analysis of peak QA-19a which is more toxic in mice than QA-19b, shows a carbohydrate composition which is similar to that of the other saponins (Table 3).

#### EXAMPLE 7

##### Isolation of Alkaline Hydrolysis Product

Treatment of QA-18 by brief alkaline hydrolysis yielded one major carbohydrate-containing alkaline hydrolysis product (designated QA-18 H). Purified QA-18 H was prepared from QA-18 and isolated in the following manner:

One ml QA-18 (5 mg/ml) was incubated with 25  $\mu$ l 1N NaOH for 15 minutes at room temperature. The reaction was stopped with the addition of 100  $\mu$ l 1N acetic acid. Using these hydrolysis conditions, QA-18 was completely converted to a major hydrolysis product (QA-18 H) eluting in a peak with retention time of 8.0 min compared to 66.8 min for unhydrolyzed QA-18, indicating the increased hydrophilicity of QA-18 H. (Chromatography on Vydac C<sub>4</sub> (4.6 mm ID×25 cm L) in 0.1% trifluoroacetic acid in 55/45 methanol/water v/v) and eluted in a gradient to 64/36 methanol/water (v/v) over 180 minutes, flow rate of 1 ml/minute). The peak containing pure QA-18 H (retention time 8.0 min) was pooled for further characterization. The hydrolysis product of QA-21, designated QA-21 H, was prepared and purified in the same manner. QA-21 H had a retention time of 9.3 minutes compared to 80.4 minutes for unhydrolyzed QA-21. These hydrolysis products were shown by retention time on HPLC and by reverse phase thin layer chromatography to be identical to the major hydrolysis products generated using the method of Higuchi et al., *Phytochemistry* 26: 229 (1987) using mild alkaline hydrolysis in NH<sub>4</sub>HCO<sub>3</sub> (Table 4). In addition, these products, QA-18 H and QA-21 H, were shown to be the major breakdown products from hydrolysis of "Quil-A", a crude saponin mixture containing QA-7, QA-17, QA-18, and QA-21 as well as other saponins, indicating that the hydrolysis products QA-21 H and QA-18 H are the same hydrolysis products isolated by Higuchi et al., supra, for structural characterization. QA-18, H and QA-21 H were saved for further characterization of adjuvant activity.

TABLE 4

Retention Time of Major Alkaline Hydrolysis Products	
QA-17 H	8.0 <sup>a</sup>
QA-18 H	8.0 <sup>a</sup>
	8.2 <sup>b</sup>
QA-21 H	9.3 <sup>a</sup>
	9.5 <sup>b</sup>
Hydrolyzed - "Quil-A"	8.2 <sup>a</sup> , 9.3 <sup>a</sup>

<sup>a</sup>Cambridge BioScience hydrolysis conditions: 5 mg/ml saponin, pH 13, reaction time = 15 minutes at room temperature

<sup>b</sup>Higuchi et al. hydrolysis conditions: 5 mg/ml saponin, 6% NH<sub>4</sub>HCO<sub>3</sub>, methanol/H<sub>2</sub>O (1/1, v/v), reaction time = 60 minutes at 100° C.

HPLC Conditions:

Vydac C<sub>4</sub>, 5  $\mu$ m particle size, 300 Å pore size, .46 × 25 cm

Solvent A = 0.1% trifluoroacetic acid in water

Solvent B = 0.1% trifluoroacetic acid in methanol

Gradient = 55-64% B/180 minutes

Flow rate = 1 ml/min

#### EXAMPLE 8

##### Testing for Adjuvant Effect Using BSA as Antigen

Briefly, adjuvant effect is assessed by increase in antigen-specific antibody titers due to addition of potential adjuvant in the immunization formulation. Increased titers result from increased antibody concentrations and/or increased antigen/antibody affinity. Adjuvant effects of saponins have previously been measured by increase in titer of neutralizing antibodies to foot-and-

mouth disease vaccines in guinea pigs (Dalsgaard, K., *Archiv. fur die gesamte Virusforschung* 44, 243-254 (1974)), increase in titer of precipitating antibodies to BSA (as measured by radial immunodiffusion) in guinea pigs vaccinated with BSA/saponin mixtures (Dalsgaard, K. *Acta Veterinaria Scandinavica* 69, 1-40 (1978)), as well as by the increase in titer of anti-keyhole limpet hemocyanin (KLH) antibody (measured by ELISA) in mice immunized with KLH/saponin (Scott, M. T., Gross-Samson, and Bomford, R., *Int. Archs. Allergy Appl. Immun.* 77:409-412 (1985)).

Assessment of adjuvant effect in this study was determined by increase in anti-BSA antibody following immunization with BSA/saponin compared with immunization with BSA in the absence of saponin. The adjuvant activity in the purified fraction was measured as follows: CD-1 mice (8-10 weeks old) were immunized intradermally with the following formulation: 10  $\mu$ g BSA (Sigma 7030, fatty acid free) and Quilaja adjuvant (at doses ranging from 1.5-45  $\mu$ g carbohydrate as measured by anthrone) in 200  $\mu$ l PBS. Sera was harvested two weeks post-immunization. Anti-BSA antibody was determined by ELISA: Immulon II plates were coated overnight at 4° C. with 100  $\mu$ l fatty acid free BSA (10  $\mu$ g/ml in PBS) in rows, A, C, E, and G. Plates were washed twice with PBS. Nonspecific binding was prevented by incubating for 1.5 h at 37° C. with 100  $\mu$ l diluent (2% Casein acid hydrolysate (Oxoid, w/v) in PBS) per well in all wells. Plates were washed four times with 0.05% Tween 20 in distilled water. Sera at dilutions of 10, 10<sup>2</sup>, 10<sup>3</sup>, and 10<sup>4</sup> were incubated in rows A+B, C+D, E+F, and G+H, respectively (100  $\mu$ l/well) for 1 h at room temperature. Plates were washed as described above. Boehringer-Mannheim horse radish peroxidase conjugate goat anti-mouse antibody (1/5000 in 5% BSA in diluent) was incubated for 30 min at room temperature (100  $\mu$ l per well, all wells). Plates were washed as described above. The extent of peroxidase reaction was determined by reaction with 2,2'-azino-bis(3-ethylbenzthiazoline)-6-sulfonate (30 minute reaction at room temperature, absorbance measured at 410 nm) or with 3,3',5,5'-tetramethylbenzidine (10 min reaction at room temperature, absorbance measured at 450 nm). The contribution of nonspecific antibody binding to the total antibody binding was removed by subtraction of the absorbance of the antigen-negative well from the absorbance of the antigen-positive well for each sera dilution. The absorbance due to antigen-specific binding was plotted as a function of the logarithm of the sera dilution. (FIG. 11) Typical endpoint titers were typically at a sera dilution of 10 or less for immunization in the absence of adjuvant and were as high as 10<sup>3</sup> in the presence of saponin adjuvant. Dialyzed, methanol-soluble bark extract at an adjuvant dose of 12  $\mu$ g carbohydrate or greater (carbohydrate assayed by anthrone) increased titers by 2 orders of magnitude compared to BSA in PBS. A good adjuvant effect was observed at doses of "Quil-A" between 9-23  $\mu$ g carbohydrate.

#### EXAMPLE 9

##### Adjuvant Testing of HPLC-Purified Extract Components

By the criteria described in Example 8, peaks QA-7, QA-11, QA-12, QA-15, QA-16, QA-17, QA-18, QA-19, and QA-20 have varying degrees of adjuvant effect with QA-15, QA-17, QA-18, QA-19, and QA-20 being particularly effective at a dose of 3.0  $\mu$ g carbohydrate in

this particular experiment. Due to the small number of mice used per immunization (2) and the natural variation in immune response between individual mice, this experiment cannot be used to quantitatively assess the relative adjuvant effect of these peaks. However, it provides a qualitative assessment of the presence of adjuvant activity. It must also be noted that the absence of apparent effect with QA-2, QA-3, QA-10, QA-13, and QA-14 does not rule out an adjuvant effect at different adjuvant doses or adjuvant/protein ratio.

Further adjuvant studies were carried out with QA-7, QA-17, and QA-18 at different protein/adjuvant ratios. In general, a good adjuvant effect was observed for QA-7, QA-17, and QA-18 when used at protein/adjuvant ratios (protein weight/carbohydrate weight) of approximately 3:1 to 9:1 (FIG. 12). QA-21 (tested in this study only at protein/carbohydrate weight of 6:1) also showed an adjuvant effect. However, it should be noted that the proper adjuvant to protein ratio for optimum immune response is a function of both the particular saponin adjuvant and the particular antigen used. Adjuvant association with antigen plays an important role in the mechanism of action of the saponin adjuvant effect. In the case of saponin binding to protein, hydrophobic interactions are the predominant factor. Hence, differences in hydrophobicity of the HPLC-purified adjuvants will affect the binding constant to hydrophobic proteins. In addition, the number of hydrophobic binding sites on the protein will also affect the ability to associate with saponin adjuvants. Hence, it is necessary to determine the optimum adjuvant dose for each individual adjuvant and antigen. Such optimization is within the skill of the art.

HPLC-purified adjuvants were also compared with Freund's complete adjuvant and were found to result in a similar level of immune response (FIG. 12, panel b).

#### EXAMPLE 10

##### Preparation of FELV Recombinant gp70R-delta

##### Inclusion Body Preparation

Recombinant *E. coli* clone R16-38 was grown in LB medium supplemented with 1% glucose and 0.1% casamino acids at 32° C. to an optical density (560 nm) of 0.4-0.6. The culture was then shifted to 42° C. and incubated for an additional 2 hours. At the end of this time the cells were collected by centrifugation at 4,000 g for 30 minutes, washed with 50 Tris HCl, pH 7.5, and finally resuspended in 200 ml 50 Tris HCl to which is added 1 ml 0.1M phenylmethylsulfonylfluoride in isopropanol (final concentration 0.5 and 0.4 ml of 5 mg/ml aprotinin (final concentration=10.0  $\mu$ g/ml). The cells were lysed by enzymatic digestion with lysozyme (final concentration=0.5 mg/ml) in the presence of 0.2% Triton X-100. After stirring for 30 minutes, 2 ml MgCl<sub>2</sub> (0.5M), 5 ml DNase I (1 mg/ml) and 1 ml 0.1M phenylmethylsulfonylfluoride were added. After stirring for 30 additional minutes, 40 ml EDTA (0.25M, pH 7.5) and 4 ml Triton X-100 (10% w/v) were added. The preparation was centrifuged at 10,000 $\times$ g for 30 minutes at 4° C., and the pellet was resuspended in 50 ml 50 Tris HCl, pH 7.5. The pellet was homogenized at low speed for 15 seconds. Lysozyme was added to a concentration of 0.5 mg/ml and 0.6 ml of 10% Triton X-100 were added. After stirring for 15 minutes, 10 ml of MgCl<sub>2</sub> (0.5M) and 1 ml DNase I (1 mg/ml) were added and stirring was continued for an additional 15 minutes. After adjusting the volume to 300 ml with 50 Tris, pH 9.0, 40 ml of 10%

Triton X-100 and 51.2 ml of EDTA (0.25M, pH 7.5) were added and the final volume adjusted to 400 ml with 50 Tris, pH 9.0. After stirring for 30 minutes, the suspension was centrifuged at  $10,000\times g$  for 30 minutes at 4° C., and the pellet was resuspended in 400 ml 50 Tris HCl, pH 7.5, containing 4M urea, 50 EDTA, and 1% Triton X-100. After stirring for 15 minutes, the suspension was centrifuged at  $10,000\times g$  for 30 minutes at 4° C., and the pellet was resuspended in 400 ml 50 Tris HCl, pH 7.5, containing 1.0M NaCl. After stirring for 15 minutes, the suspension was centrifuged at  $10,000\times g$  for 30 minutes at 4° C., and the pellet was resuspended in 400 ml 50 Tris HCl, pH 7.5, containing 6M urea, and 5 EDTA. After stirring for 15 minutes, the suspension was centrifuged at  $10,000\times g$  for 30 minutes at 4° C. At this point the pellet of inclusion bodies was either frozen for future use or solubilized in 50 Tris HCl, pH 9.5, containing 6M guanidine HCl, 50 EDTA, and 0.5% beta-mercaptoethanol. The gp70R-delta polypeptide was then purified by either of the methods of Example 11, below.

#### EXAMPLE 11

##### Purification of FeLV Recombinant gp70R-delta

###### Procedure I

The solubilized protein of Example 8 was dialyzed against 6M urea, 50 Tris-Cl, pH 8.0, 5 EDTA, and 1 dithiothreitol (DTT). Approximately 120 mg of the protein was applied to a CM-TSK column (EM Science, 1.5 cm ID $\times$ 4 cm) equilibrated with the same buffer. The protein was eluted with a linear gradient of NaCl (0–1.0M in 150 ml) in the same buffer. The fractions were collected and analyzed by electrophoresis on 10% SDS-polyacrylamide gels. Coomassie-staining was used to identify the gp70R-delta protein. Fractions 25–31, eluting at approximately 0.1M NaCl, were pooled and used for immunization.

###### Procedure II

In order to decrease the hydrophobicity of gp70R-delta, the sulfhydryl groups were alkylated with iodoacetamide and the lysine residues were N-acylated with citraconic anhydride. The protein prepared as in Example 8 was solubilized in 6M guanidine-HCl in 50 mM borate, pH 9.0, 0.5% beta-mercaptoethanol (v/v). Iodoacetamide is added at a molar ratio of 1:1 (iodoacetamide:total sulfhydryl groups). The alkylation was carried out in the dark for 1 hour at room temperature. The alkylation of all sulfhydryl groups (in the protein and beta-mercaptoethanol) was monitored with DTNB (Ellman's reagent) to ensure complete alkylation. The protein concentration was adjusted to 2 mg/ml.

The protein was citraconylated in the dark by the addition of citraconic anhydride (0.0022 ml per mg protein; approximately 50 molar excess over free lysines). The preparation was dialyzed several times in the dark against 50 mM borate, pH 9.0. The completion of the acylation of the protein lysine groups was determined by reaction with trinitrobenzene sulfonic acid (TNBS) which measures residual free lysine groups. TNBS (200  $\mu$ l of 10 mM) was added to 200  $\mu$ g alkylated, citraconylated, dialyzed gp70R-delta in 1 ml 50 mM sodium borate, pH 9.0. The mixture was incubated for 2 hours in the dark at 40° C., the reaction quenched with 0.5 ml of 1N HCl and 0.5 ml 1% SDS, and the absorbance was read at 340 nm. The concentration of

TNP-lysine was determined using a molar extinction coefficient of 10,400.

The purification of the alkylated, citraconylated gp70R-delta was performed at pH 9.0 to prevent de-blocking of lysine groups. Urea at a final concentration of 4M was added to the modified protein. The protein was concentrated to 3 mg/ml by ultrafiltration and applied to a Sepharose 6B-Cl column (1.5 $\times$ 86 cm). The gp70R-delta protein was eluted at a flow rate of 6.6 ml/hr with 4M urea, 50 mM sodium borate, pH 9.0. Fractions (5.3 ml/fraction) were collected and the gp70R-delta was determined by protein assay and SDS-polyacrylamide electrophoresis to be in fractions 13–15.

The citraconylation of gp70R-delta was reversed by dialyzing 5 ml of alkylated, citraconylated gp70R-delta (1.0 mg/ml) against 6M urea in 50 mM sodium citrate, pH 5.5 for 48 hours at room temperature. The gp70R-delta was dialyzed against 6 M urea in 100 mM sodium bicarbonate, pH 8.0 and the protein concentration adjusted to 0.8 mg/ml prior to absorption to aluminum hydroxide.

###### Procedure III

A modification of the above purification of alkylated, citraconylated gp70R-delta was developed. Briefly, alkylated, citraconylated gp70R-delta is modified and dialyzed against 50 mM sodium borate, pH 9.0 as described above. Urea was added to a final concentration of 8.0M. The protein was concentrated by ultrafiltration with a PM-30 membrane to yield 2.5 mg protein/ml. The protein solution was applied to a Sepharyl S-400 column (1.5 $\times$ 90 cm) in a 50 mM sodium borate buffer, pH 9.0 containing 8M urea and eluted with the same buffer. Fractions (2.9 ml/fraction) were collected and fractions 34–37 containing gp70R delta were pooled. Twenty-one mg of the protein from these fractions were diluted to a final concentration of 4M urea with 50 mM sodium borate, pH 9.0 and applied to a DEAE-TSK column (1.5 $\times$ 11 cm). The protein was eluted with a linear gradient of NaCl (0–0.5M) in 50 mM sodium borate, pH 9.0 containing 4M urea. Three ml fractions were collected. Fractions 89–95 containing gp70R-delta were pooled and 15 mg of gp70R-delta was recovered.

#### EXAMPLE 12

##### Immunization with Aluminum Hydroxide-Absorbed gp70R-delta

Aluminum hydroxide which has been found to have an adjuvant effect for many proteins and is coolly used in vaccines was used as a carrier for gp70R-delta. gp70Rdelta prepared by procedure I of Example 11 above absorbs tightly to 10% aluminum hydroxide in the presence of 50 mM Tris-Cl, pH 8.0 containing 6M urea. Approximately 3  $\mu$ g gp70R-delta were absorbed per 100  $\mu$ g aluminum hydroxide. The gp70R-delta absorbed to the aluminum hydroxide was washed with phosphate buffered saline (PBS), resuspended in PBS and used for immunization of animals.

CD-1 mice (8–10 weeks old) were immunized intradermally with gp70R-delta absorbed to Al(OH)<sub>3</sub> in a total volume of 200  $\mu$ l PBS in the presence and absence of HPLC-purified saponins QA-17 or QA-18 or a mixture of QA-17 and QA-18. Twenty to twenty-five  $\mu$ g of gp70R-delta were injected per dose. HPLC-purified saponins QA-17 or QA-18 or a mixture of QA-17 and QA-18 were used at a dry weight dose of 10  $\mu$ g. Two mice were injected for each formulation. Mice were given a booster injection of gp70R-delta/aluminum

hydroxide six weeks after the initial injection. Mouse sera was analyzed for reactivity to FEA, a FeLV subgroup A, at 2, 4, and 8 weeks post-immunization by an ELISA immunoassay. Four weeks following immunization, an anti-FeLV response elicited by the recombinant gp70-delta was observed. HPLC-purified saponin adjuvants QA-17 and QA-18 boost this response. The response was two orders of magnitude greater at four weeks post-immunization in the presence of QA-17 compared to immunization in the absence of saponin adjuvant. The results of this experiment are shown in FIG. 13.

Anti-FEA antibody was assayed by an ELISA assay. FEA virus (10 µg/ml in PBS) was absorbed to Immulon II plates overnight at 4° C. (100 µl/well). The plates were washed with PBS and nonspecific antibody binding was blocked by incubation for 1 hour with 10% normal goat serum in PBS (100 µl/well) at room temperature. Plates were then washed with 0.05% Tween-20 in distilled water. Sera was diluted in 10% normal goat serum in PBS and incubated for 1 hour at room temperature on the plate at serum dilutions of 10, 10<sup>2</sup>, 10<sup>3</sup>, and 10<sup>4</sup> (100 µl/well). After washing the plates with 0.05% Tween-20 in distilled water, they were incubated for 30 minutes at room temperature with 100 µl/well of peroxidase-conjugated goat anti-mouse IgG (Boehringer-Mannheim) diluted 1/5000 in PBS. After washing the plates with 0.05% Tween-20 in distilled water, the amount of IgG-binding was determined by peroxidase reaction with 3,3',5,5'-tetramethylbenzidine from the absorbance at 450 nm determined on a Dynatech microliter plate reader.

#### EXAMPLE 13

##### Immunization with Aluminum Hydroxide-Absorbed Alkylated gp70R-delta

CD-1 mice (8-10 weeks old) were immunized intradermally with 15 µg/dose of alkylated gp70R-delta purified by procedure II of Example 11 (absorbed to aluminum hydroxide as described in Example 12) in 200 µl PBS. HPLC-purified adjuvants AQ-7, AQ-17, AQ-18 and mixtures of the three adjuvants were used at a dry weight dose of 10 µg. Three mice were injected for each formulation. Mouse sera was analyzed by ELISA at 2 and 4 weeks postimmunization for reactivity to FEA as described in Example 10. As with immunization with unmodified gp70R-delta shown in Example 10, immunization with alkylated gp70R-delta elicits an anti-FeLV viral response by four weeks post-immunization. HPLC-purified adjuvants QA-7, QA-17, QA-18 all increase the immune response as compared to immunization in the absence of the saponin adjuvants. QA-17 and mixtures of QA-17 and QA-18 induced the highest response, inducing endpoint titers almost two orders of magnitude greater than immunization in the absence of saponin adjuvants. The results of these experiments are summarized on FIG. 14.

#### EXAMPLE 14

##### Toxicity of QA-7, QA-17, QA-18, QA-19, QA-21, "Quil-A"

With crude Quillaja saponins, a major symptom of toxicity in mice appears as necrosis of the liver. Purified saponins were injected into mice to determine effects on the liver. Mice were injected intradermally with 150 µg each QA-7, QA-17, QA-18, QA-21 and "Quil-A", the crude saponin extract used as the raw material for the purification of the other components. Animals injected

with QA-7, QA-17, QA-18, and QA-21 appeared mildly ill initially but appeared to recover fully within a few hours after injection. "Quil-A" caused severe symptoms which continued for 48 hours. All mice were sacrificed at 48 hours for post-mortem examination of the liver. "Quil-A" caused severe damage of the liver with multifocal areas of acute necrosis evident. QA-7, QA-17, QA-18, and QA-21 did not seem to significantly affect the liver. QA-17 and QA-18 were also tested in kittens with subcutaneous injection of 100 µg each at 8 and 10 weeks, with no toxicity observed clinically or in the blood chemistry. In contrast, "Quil-A" induced a pyrogenic response which persisted for several hours in kittens. Hence, the purified saponins appear to be less toxic than "Quil-A" in both mice and kittens indicating that the purification process separates these saponins from one or more toxic components present in a crude Quillaja extract. One such toxic component has tentatively been identified as QA-19; dosages of 50 µg or greater were lethal in mice within a few days of injection. Further purification of QA-19 indicated that it could be separated into two peaks, QA-19a and QA-19b. QA-19a was lethal in mice at doses of 100 µg or greater whereas QA-19b was apparently nonlethal up to dose of 150 µg; hence, a synergistic effect to produce increased toxicity in the mixture of QA-19a and QA-19b cannot be ruled out. Preliminary screening of other minor peaks isolated from "Quil-A" indicates that other fractions may also be toxic. Hence, the purification protocols allow the separation of adjuvant-active saponins from similar but distinct compounds which are more toxic or which cochromatograph with toxic contaminants.

#### EXAMPLE 15

QA-18H and QA-21H, prepared as described in Example 7, were tested for adjuvant effect with BSA in direct comparison with the unhydrolyzed original products QA-18 and QA-21 prepared as described in Examples 3 and 4. QA-18 and QA-21 increase the humoral immune response to BSA in mice by at least an order of magnitude by two weeks post-immunization. However, the hydrolysis products QA-18H and QA-21H at the same weight dosage do not increase the response significantly (FIG. 15). Hence, optimal adjuvant effect is observed with the intact saponins; the essential structure required for adjuvant activity is lost or altered when QA-18 and QA-21 are hydrolyzed to QA-18H and QA-21H, respectively.

The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention as set forth below.

What is new and intended to be covered by Letters Patent of the United States is:

1. Substantially pure saponin purified from a crude *Quillaja saponaria* extract wherein said pure saponin is characterized by a single predominant peak which comprises 90% or more of the total area of all peaks of a chromatogram, excluding the solvent peak, when analyzed on reverse phase-HPLC on a Vydac C<sub>4</sub> column having 5 µm particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/mixture, and wherein said saponin has immune adjuvant activity and is less toxic when used as an adjuvant than said *Quillaja saponaria* extract.

2. Substantially pure QA-7 saponin purified from a crude *Quillaja saponaria* extract wherein said pure saponin is characterized by one predominant peak which comprises 90% or more of the total area of all peaks of a chromatogram, excluding the solvent peak, and having a retention time of approximately 9–10 minutes when analyzed on reverse phase HPLC on a Vydac C<sub>4</sub> column having 5  $\mu$ m particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/minute.

3. The substantially pure QA-7 saponin of claim 2, wherein said saponin has immune adjuvant activity, and wherein said saponin is characterized by a carbohydrate content of about 35% per dry weight as assayed by anthrone, has a UV adsorption maxima of 205–210 nm, has a micellar concentration of 0.06% (w/v) in water and 0.07% in phosphate buffered saline, and causes no detectable hemolysis of sheep red blood cells at concentrations of 200  $\mu$ g/ml.

4. The substantially pure QA-7 saponin of claim 3, wherein said carbohydrate content has a composition comprising the monosaccharides: terminal rhamnose, terminal xylose, terminal glucose, terminal galactose, 3-xylose, 3,4-rhamnose, 2,3-fucose, 2,3-glucuronic acid and apiose.

5. Substantially pure QA-21 saponin purified from a crude *Quillaja saponaria* extract wherein said pure saponin is characterized by one predominant peak which comprises 90% or more of the total area of all peaks of a chromatogram, excluding the solvent peak, and having a retention time of approximately 51 minutes when analyzed on reverse phase-HPLC on a Vydac C<sub>4</sub> column having 5  $\mu$ m particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/minute.

6. The substantially pure QA-21 saponin of claim 5, wherein said saponin has immune adjuvant activity, and wherein said saponin is characterized by a carbohydrate content of about 22% per dry weight as assayed by anthrone, has a UV absorption maxima of 205–210 nm, has a micellar concentration of about 0.03% (w/v) in water and 0.02% (w/v) in phosphate buffered saline, and causes hemolysis of sheep red blood cells at concentrations of 25  $\mu$ g/ml or greater.

7. The substantially pure QA-21 saponin of claim 6, wherein said carbohydrate content has a composition comprising the monosaccharides: terminal rhamnose, terminal arabinose, terminal apiose, terminal xylose, 4-rhamnose, terminal glucose, terminal galactose, 2-fucose, 3-xylose, 3,4-rhamnose and 2,3-glucuronic acid.

8. A substantially pure QA-17 saponin purified from a crude *Quillaja saponaria* extract wherein said pure saponin is characterized by one predominant peak which comprises 90% or more of the total area of all peaks of a chromatogram, excluding the solvent peak, and having a retention time of approximately 35 minutes on reverse phase-HPLC on a Vydac C<sub>4</sub> column having 5  $\mu$ m particle size, 330 Å pore, 4.6 mm ID×25 cm L in a

solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/minute.

9. The substantially QA-17 saponin of claim 8, wherein said saponin has immune adjuvant activity, and wherein said saponin is characterized by a carbohydrate content of about 29% per dry weight as assayed by anthrone, has a UV absorption maxima of 205–210 nm, has a micellar concentration of about 0.06% (w/v) in water and 0.03% (w/v) in phosphate-buffered saline, and causes hemolysis of sheep red blood cells at concentrations of 25  $\mu$ g/ml.

10. The substantially pure QA-17 saponin of claim 9, wherein said carbohydrate content has a composition comprising the monosaccharides: terminal rhamnose, terminal xylose, 2-fucose, 3-xylose, 3,4-rhamnose, 2,3-glucuronic acid, terminal glucose, 2-arabinose, terminal galactose and apiose.

11. A substantially pure QA-18 saponin purified from a crude *Quillaja saponaria* extract wherein said pure saponin is characterized by one predominant peak which comprises 90% or more of the total area of all peaks of a chromatogram, excluding the solvent peak, and having a retention time of approximately 38 minutes on reverse phase-HPLC on a Vydac C<sub>4</sub> column having 5  $\mu$ m particle size, 330 Å pore, 4.6 mm ID×25 cm L in a solvent of 40 mM acetic acid in methanol/water (58/42; v/v) at a flow rate of 1 ml/minute.

12. The substantially QA-18 saponin of claim 11, wherein said saponin has immune adjuvant activity, and wherein said saponin is characterized by a carbohydrate content of about 25–26% per dry weight as assayed by anthrone, has a UV absorption maxima of 205–210 nm, has a micellar concentration of 0.04% (w/v) in water and 0.02% (w/v) in phosphate-buffered saline, and causes hemolysis of sheep red blood cells at concentrations of 25  $\mu$ g/ml.

13. The substantially pure QA-18 saponin of claim 12, wherein said carbohydrate content has a composition comprising the monosaccharides: terminal rhamnose, terminal arabinose, terminal apiose, terminal xylose, terminal glucose, terminal galactose, 2-fucose, 3-xylose, 3,4-rhamnose and 2,3-glucuronic acid.

14. A method of enhancing an immune response to an antigen in an individual comprising administration of an amount of the substantially pure saponin adjuvants from any of claims 1–7 and 8–13 to said individual in an amount sufficient to enhance the immune response of said individual to said antigen.

15. A pharmaceutical composition useful for inducing the production of antibodies to an antigen in an individual comprising an immunogenically effective amount of an antigen and at least one substantially pure saponin as in any one of claims 1–7 and 8–13, wherein said substantially pure saponin is present in an amount sufficient to enhance the immune response of said individual to said antigen.

16. The pharmaceutical composition of claim 15, wherein said individual is a mammal.

\* \* \* \* \*

**UNITED STATES PATENT AND TRADEMARK OFFICE**  
**CERTIFICATE OF CORRECTION**

**PATENT NO. :** 5,057,540

Page 1 of 2

**DATED :** October 15, 1991

**INVENTOR(S) :** Charlotte A. Kensil, et al

**It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:**

Column 10, line 32, "40 nM" should read "40 mM".

Column 11, Table 2, last line, under the heading "HPLC Fraction" there should be a dash " - " to denote that no fraction was included as adjuvant with the antigen.

Column 12, line 1, "QA-17" should read "QA-7".

Column 20, line 49, "coolly" should read "commonly".

Column 21, line 32, "microliter" should read as "microtiter".

UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION

PATENT NO. : 5,057,540

Page 2 of 2

DATED : October 15, 1991

INVENTOR(S) : Charlotte A. Kensil, et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 21, lines 41 and 42, "AQ-7, AQ-17, AQ-18" should read "QA-7, QA-17, and QA-18".

Column 23, line 22, "monosuccharides" should read "monosaccharides".

Column 24, line 1, "mN" should read "mM".

Signed and Sealed this  
First Day of June, 1993

Attest:



MICHAEL K. KIRK

Attesting Officer

Acting Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 5,057,540  
APPLICATION NO. : 07/573268  
DATED : October 15, 1991  
INVENTOR(S) : Charlotte A. Kensil and Dante J. Marciani

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At column 4, line 53, "330 Å" should be -- 300 Å --.

At column 5, line 66, "330 Å" should be -- 300 Å --.

At column 6, line 2, "330 Å" should be -- 300 Å --.

At column 6, line 18, "330 Å" should be -- 300 Å --.

At column 6, line 22, "330 Å" should be -- 300 Å --.

At column 6, line 39, "330 Å" should be -- 300 Å --.

At column 6, line 43, "330 Å" should be -- 300 Å --.

At column 6, line 59, "330 Å" should be -- 300 Å --.

At column 6, line 62, "330 Å" should be -- 300 Å --.

At column 9, line 43, "330 Å" should be -- 300 Å --.

At column 10, line 31, "330 Å" should be -- 300 Å --.

At column 12, line 56, "1980" should be -- 1988 --.

In claim 1, at column 22, line 63, "330 Å" should be -- 300 Å --.

In claim 2, at column 23, line 8, "330 Å" should be -- 300 Å --.

In claim 5, at column 23, line 33, "330 Å" should be -- 300 Å --.

In claim 8, at column 23, line 59, "330 Å" should be -- 300 Å --.

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 5,057,540  
APPLICATION NO. : 07/573268  
DATED : October 15, 1991  
INVENTOR(S) : Charlotte A. Kensil and Dante J. Marciani

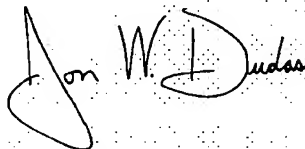
Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In claim 11, at column 24, line 25, "330 Å" should be -- 300 Å --.

Signed and Sealed this

Thirty-first Day of July, 2007

A handwritten signature in black ink, reading "Jon W. Dudas". The signature is stylized, with a large, looped initial "J" and a distinct "D".

JON W. DUDAS

*Director of the United States Patent and Trademark Office*